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OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

FOR

1896.

(INCORPORATED 1881.)

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ERRATA.

Page 222, line 5, instead of 3·578, *read* 3·534
" " " 18, " 3·578, " 3·534
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1891		Hanly, Charles, L.S., Resident Engineer, Roads and Bridges Office, Crookwell.
1890		Harris, Rev. Edward, M.A. *Oxon.* and *Syd.*, D.D. *Oxon.*
1881		‡Harris, John, 'Bulwarra,' Jones-street, Ultimo.
1877	P 14	‡Hargrave, Lawrence, J.P., Stanwell Park, Clifton.
1884		Haswell, William Aitcheson, M.A., D.Sc., F.L.S., Professor of Zoology and Comparative Anatomy, University, Sydney; p.r. St. Vigeans, Darling Point.
1896		Hay, Alexander, Coolangatta, N.S.W and Australian Club.
1890		Haycroft, James Isaac, M.E. Queen's Univ. *Irel.*, Assoc. M. Inst. C.E., L.S., 'Fontenoy,' Ocean-street, Woollahra.
1876		Heaton, J. Henniker, M.P., St. Stephen's Club, Westminster, London.
1891	P 1	Hedley, Charles, F.L.S., Assistant in Zoology, Australian Museum, Sydney.
1893		Henderson, John, C.E.

Elected		
1890		Henry, Arthur Geddes, M.B., Ch.M. *Syd.*, Resident Medical Officer, Callan Park Asylum, Balmain.
1884		Henson, Joshua B., C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1891		Hickson, Robert, M. Inst. C.E., Under Secretary, Public Works Department, p.r. 'The Pines,' Bondi.
1876	P 2	Hirst, George D., 377 George-street.
1896		Hinder, Henry Critchley, M.B., C.M. *Syd.*, Elizabeth-st. Ashfield.
1891		Hood, Alexander Jarvie, M.B., Mast. Surg. *Glas.*, 219 Macquarie-street, City.
1892		Hodgson, Charles George. 157 Macquarie-street.
1886		Holmes, Spencer Harrison, 'The Wilderness,' Allandale, Hunter River.
1891		Houghton, Thos. Harry, A.M.I.C.E., M.I.M.E., 12 Spring-street.
1879		Houison, Andrew, B.A., M.B., C.M. *Edin.*, 47 Phillip-street.
1891	P 1	How, William F., M. Inst. C.E., M. I. Mech. E., Wh. Sc., Mutual Life Buildings, George-street.
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., F. R. Met. Soc., Second Meteorological Assistant, Sydney Observatory.
1882		Hurst, George, M.A. *Syd.*, M.B. Univ. *Lond.*, M.B., C.M. Univ. *Edin.*, Bathurst.
1886		Hutchinson, W. A., Bond-street, p.r. 'Alston,' Glebe Point.
1891		Hutchinson, William, M. Inst, C.E., Supervising Engineer, Railway Construction Branch, Public Works Department.
1895		Jacob, Albert Francis, A.M.I.C.E., 8 The Terrace, Shepherd's Hill, Newcastle.
1891		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 157 Liverpool-street, Hyde Park.
1884		Jenkins, Edward Johnstone, M.A., M.D. *Oxon.*, M.R.C.P , M.R.C.S. L.S.A. *Lond.*, 213 Macquarie-street, North.
1879		Johnson, James W., Norwich Chambers, Hunter-street.
1887		Jones, George Mander, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 'Viwa,' Burlington Road, Homebush.
1874		Jones, James, 'Miltonia,' Randwick.
1879		Jones, John Trevor, C.E., 'Tremayne,' North Shore.
1884		Jones, Llewellyn Charles Russell, M.L.A., Solicitor, 130 Pitt-st.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park, p.r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Caer Idris,' Ashfield.
1891		Jones, Robert E., M. Inst. C.E., Roads Department, Muswellbrook.
1875	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.
1883		Kater, The Hon. H. E., M.L.C., 'Tusculum,' Macleay-street, Pott's Point.
1873		Keele, Thomas William, M. Inst. C.E., District Engineer, Harbours and Rivers Department, Ballina, Richmond River.
1877		Keep, John, Broughton Hall, Leichhardt.

Elected		
1884		Kendall, Theodore M., B.A., L.R.C.P., L.R.C.S. *Lond.*, L.M., 28 College-street, Hyde Park.
1894		Kelly, Walter MacDonnell, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S., *Glas.*, 265 Elizabeth-street.
1887		Kent, Harry C., Bell's Chambers, 129 Pitt-street.
1892	P 2	Kiddle, Hugh Charles, F. R. Met. Soc., Public School, Seven Oaks, Smithtown, Macleay River.
1891		King, Christopher Watkins, A.M.I.C.E., L S., Roads and Bridges Branch, Public Works Department, Sydney.
1874		King, The Hon. Philip G., M.L.C., 'Banksia,' William-street, Double Bay.
1896		King, Kelso, 'Glenhurst,' Darling Point.
1892		Kirkaldie, David, Chief Traffic Manager, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.C.S. *Irel.*, 5 Lyons' Terrace, Hyde Park.
1881	P 5	Knibbs, G. H., F.R.A.S., L.S., Lecturer in Surveying, University of Sydney, p.r. 'Avoca House,' Denison Road, Petersham. *Hon. Secretary.*
1877		Knox, Edward W., J.P., 'Rona,' Bellevue Hill, Double Bay.
1875		Knox, The Hon. Edward, M.L.C., O'Connell-street.
1877		Kopsch, G., 'Saxonia,' Boulevard, Petersham.
1878		Kyngdon, F. B., F.R.M.S. *Lond.*, Deanery Cottage, Bowral.
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1872	P 45	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F.R.S.; Assoc. Roy. Sch. Mines *Lond.*; F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.*; Mem. Phy. Soc. *Lond.*; Mineralogical Society, *Lond.*; Edin. Geol. Soc.; Mineralogical Society, *France*; Cor. Mem. Edin. Geol Soc.; Roy. Soc. *Tas.*; Roy. Soc. *Queensland*; Senckenberg Institute, *Frankfurt*; Society d' Acclimat. *Mauritius*; Hon. Mem. Roy. Soc. *Vict.*; N. Z. Institute; K. Leop. Carol. Acad. *Halle a/s*; Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point.
1881		Lloyd, Lancelot T., 'Eurotah,' William-street East.
1874		Lloyd, The Hon. George Alfred, M.L.C., F.R.G.S., 'Scottforth,' Elizabeth Bay.
1890	P 2	Loir, Adrien.
1887		Long, Alfred Parry, Registrar General, Elizabeth-street.
1878		Low, Hamilton, H. M. Customs, Sydney.
1887		MacAllister, John F., M.B., B.S. *Melb.*, 'Ewhurst,' Stanmore Road, Stanmore.
1892		MacCarthy, Charles W., M.D., F.R.C.S. *Irel.*, 223 Elizabeth-street, Hyde Park.
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.

Elected		
1874		M'Cutcheon, John Warner, Assayer to the Sydney Branch of the Royal Mint.
1892		McDonagh, John M., B.A., M.D., M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street North.
1878		MacDonald, Ebenezer, 'Kamilaroi,' Darling Point.
1886		MacDonald, John A., M. Inst. C.E., M. Inst. M.E., M. Am. Soc. C.E.
1868		MacDonnell, William J., F.R.A.S., c/o Mr. W. C. Goddard, Norwich Chambers, Hunter-street.
1877		MacDonnell, Samuel, Cape's Chambers, 3 Bond-street.
1891		McDouall, Herbert Crichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Hospital for Insane, Gladesville.
1891		McKay, Robert Thomas, L.S.
1893		McKay, William J. Stewart, B. Sc., M.B., Ch. M., 'Tara,' Edgeware Road, Enmore.
1876		Mackellar, The Hon. Charles Kinniard, M.L.C., M.B., C.M. *Glas.*, 183 Liverpool-street, Hyde Park.
1872		Mackenzie, John, F.G.S., Athenæum Club, Sydney.
1876		Mackenzie, Rev. P. F., The Manse, Johnston-st., Annandale.
1880	P 5	M'Kinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst, C.E., Chief Engineer for Water Conservation, Athenæum Club, Castlereagh-street.
1876		MacLaurin, The Hon. Henry Norman, M.L.C. M.A.. M.D. *Edin.*, L.R.C.S. *Edin.*, LL.D. Univ. *St. Andrews*. 155 Macquarie-st.
1894		McMillan, William, M.L.A. 'St. Kilda,' Allison-st., Randwick.
1882	P 1	Madsen, Hans. F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 5	Maiden, Joseph H., F.L.S., F.C.S., Corr. Memb. Pharm. Soc. Great Britain, and of Roy. Soc., S.A.; Hon Memb. Phila. Coll. of Pharm. and Royal Netherlands Soc., (Haarlem); Director, Botanic Gardens, Sydney. *President.*
1878		Maitland, Duncan Mearns, District Surveyor, Armidale.
1873		Makin, G. E., Market Square, Berrima.
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1877		Mann, John F., 'Kerepunu,' Neutral Bay.
1876		Manning, Frederic Norton, M.D Univ. *St. And.*, M R.C.S. *Eng.*, L.S.A. *Lond.*, Hunter's Hill.
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1880		Marano, G. V., M.D, Univ. *Naples*, Clarendon Terrace, Elizabeth-street.
1893	P 4	Martin, Charles J., D. Sc., M.B. *Lond.*, M.R.C.S. *Eng.*, Demonstrator of Physiology, Sydney University, p.r. 225 Macquarie-st.
1879		Matthews, Robert Chr., Sheridan-street, Gundagai.
1875	P 3	Mathews, Robert Hamilton, L.S , Cor. Mem. Anthrop. Inst. Gt. Brit. and Irel ; Cor. Mem. Roy. Geogr. Soc. Aust., Queensland, 'Carcuron,' Hassall-street, Parramatta.
1888		Megginson, A. M., M.B., C.M. *Edin.*, 177A Liverpool-street.
1896		Merfield, Charles J., F.R.A.S., Railway Construction Branch, Public Works Department, p.r. 'Lincoln Cottage,' Day-street, Marrickville.
1893		Millard, Reginald Jeffery, M.B., Ch.M. *Syd.*, Hospital for Insane, Callan Park, Balmain.
1887		Miles, George E., L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, Hospital for Insane, Newcastle.
1873		Milford, F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 3 Clarendon Terrace, 295 Elizabeth-street.
1882		Milson, James, 'Elamang,' North Shore.

Elected		
1893		Nangle, James, Architect, Australia-street, Newtown.
1890		Neill, Leopold Edward Flood, M.B., Ch. M., Univ. *Syd.*, No. 3, Bayswater Houses, Double Bay.
1891		Noble, Ewald George, 60 Louisa Road, Longnose Point, Balmain.
1873		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street, p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., 'Waima,' Wentworth Road, Point Piper, Sydney.
1878		Ogilvy, James L., Melbourne Club, Melbourne.
1888		O'Neill, G. Lamb, M.B., C.M. *Edin.*, 291 Elizabeth-street.
1896		Onslow, Major James William Macarthur, Camden Park, Menangle.
1883		Oram, Arthur Murray, M.D. Univ. *Edin.*, 213 Macquarie-street, North.
1875		O'Reilly, W. W. J., M D., M.Ch. Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street.
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1893		Owen, Captain Percy Thomas, Victoria Barracks, and Australian Club.
1883		Palmer, Joseph, 133 Pitt-st., p.r. Kenneth-st,, Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1877		Pedley, Perceval R., 227 Macquarie-street.
1877		Perkins, Henry A., 'Barangah,' Coventry Road, Homebush.
1881		Philip, Alex., L.K.Q.C.P. *Irel.*, L.R.C.S. *Irel.*, 574 Crown-street, Surry Hills.
1876		Pickburn, Thomas. M. D., C. M. *Aberdeen*, M. R. C. S. *Eng.*, 22 College-street.
1879	P 4	Pittman, Edward F., Assoc. R.S.M., L.S., Government Geologist, Department of Mines.
1881		Poate, Frederick, District Surveyor, Tamworth.
1890		Pockley, Francis Antill, M.B., M. Ch. Univ. *Edin.*, M.R.C.S. *Eng.*, 227 Macquarie-street.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887		Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B.Sc. *Syd.*, Demonstrator in Physics, Sydney University.
1891		Poole, William Jr., Assoc. M. Inst. C.E., 87 Pitt-street, Redfern.
1896		Pope, Roland James, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 235 Macquarie-street.
1882	P 5	Porter, Donald A., Tamworth.
1897	P 1	Portus, A. B., Assoc. M. Inst. C.E., Superintendent of Dredges, Public Works Department.
1893		Purser, Cecil, B.A., M.B., Ch.M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1876		Quaife, Frederick H., M.A., M.D., Master of Surgery *Glas.*, 'Hughenden,' 19 Queen-street, Woollahra.

Elected		
1865	P 1	‡Ramsay, Edward P., LL.D. Univ. St. And., F.R.S.E., F.L.S., Australian Museum.
1868		Reading, E., Mem. Odont. Soc. *Lond.*, Elizabeth-street, Hyde Park, p.r. Fullerton-street, Woollahra.
1888		Reading, Richard Fairfax, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.D.S. *Eng.*, 151 Macquarie-street.
1881	P 3	Rennie, Edward H., M.A. *Syd.*, D.Sc. *Lond.*, Professor of Chemistry, University, Adelaide.
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 16 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, M.L.C., B.A. *Syd.*, M.D., F.R.C.S. *Edin.*, 295 Elizabeth-street.
1868	P 4	Roberts, Sir Alfred, M.R.C.S. *Eng.*, Hon. Mem. Zool. and Bot. Soc. *Vienna*, 125 Macquarie-street North.
1893	P 1	Roberts, W. S. de Lisle, C.E., Sewerage Branch, Public Works Department, Phillip-street.
1885		Rolleston, John C., C.E., Harbours and Rivers Branch, Dept. of Public Works.
1897		Ronaldson, James Henry, Mining Engineer, 32 Macleay-st., Pott's Point.
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, Hospital for the Insane, Kenmore, near Goulburn.
1895		Ross, Colin John, B.Sc., B.E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895	P 1	Ross, Herbert E., Consulting Mining Engineer, 121 Pitt-st.
1865		Ross, J. Grafton, O'Connell-street.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-st., and Union Club.
1894		Rowney, George Henry, Assoc. M. Inst. C.E., Water and Sewerage Board, Pitt-street; p.r. 'Maryville,' Ben Boyd Road, Neutral Bay.
1864	P 61	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F. R. Met. Soc., Hon. Memb. Roy. Soc., South Australia, Government Astronomer, Sydney Observatory.
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 379*b* George-street; p.r. 'Mahurn,' Milton-street, Ashfield.
1883		Rygate, Philip W., M.A., B.E. *Syd.*, 98 Pitt-street.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., University, Sydney.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1886		Scott, Walter, M.A. *Oxon.*, Professor of Greek, University, Sydney.
1891		Seaver, Thomas Whitechurch, B.C.E. Roy. Univ. *Irel.*, Water Conservation Branch, Public Works Department.
1877	P 1	Selfe, Norman, M. Inst. C.E., M. Inst. M.E., Victoria Chambers, 279 George-street.
1890	P 1	Sellors, R. P. B.A. *Syd.*, F.R.A.S., Sydney Observatory.
1891		Selman, D. Codrington, Wh. Sc., St. James's Chambers, King-street, City.

Elected		
1891		Shaw, Percy William, Assoc. M. Inst. C.E., Resident Engineer for Tramway Construction, 'Leswell,' Torrington Road, Strathfield.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Divisional Engineer, Railway Department, Goulburn.
1879		Shepard, A. D., Box 728 G.P.O. Sydney.
1875		Sheppard, Rev. G., B.A. *Syd.*, Berrima.
1882		Shewen, Alfred, M.D. Univ. *Lond.*, M.R.C.S. *Eng.*, 6 Lyons' Terrace, Hyde Park.
1894		Simpson, Benjamin Crispin, M. Inst. C.E., 113 Phillip-street.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Hospital for the Insane, Gladesville.
1893		Sinclair, Russell, M.I.M.E. &c., Consulting Engineer, 97 Pitt-st.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1891	P 1	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 3	Smeeth, William Frederick, M.A., B.E., F.G.S., A.R.S.M., Geological Department of Mysore, Bangalore, India.
1893	P 14	Smith, Henry G., F.C.S., Mineralogist, Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, Denison-street, Woollahra.
1875		Smith, Robert, M.A. *Syd.*, Marlborough Chambers, 2 O'Connell-street.
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department, N. Sydney.
1896		Smyth, Selwood, Harbours and Rivers Branch, Public Works Department.
1892		Speak, Savannah J., Assoc. R. S. M.
1896		Spencer. Walter, M.D. *Brux.*, 13 Edgeware Road, Enmore.
1893		Spencer, Thomas William Loraine, Resident Engineer, Roads and Bridges, Armidale.
1879		Spry, James Monsell, Rylstone.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., 'Fenella,' Frederick-street, Rockdale.
1892		Statham, Hugh Worthington, Roads Office, Gosford.
1882		Steel, John, L.R.C.P., L.R.C.S. *Edin.*, Ch.M. B.S. Univ. *Melb.*, 3 Lyons' Terrace, Hyde Park.
1889		Stephen, Arthur Winbourn, L.S., 86 Pitt-street.
1879		‡Stephen, The Hon. Septimus A., M.L.C., 12—14 O'Connell-st.
1891		Stilwell, A. W., Assoc. M. Inst. C.E., 'Strathroy,' East Orange.
1892		Stuart, Charles McDonnell, B.E. Queen's Univ. *Irel.*, M. Inst. C.E., 'Dunseverick,' Pymble.
1883	P 3	Stuart, T. P. Anderson, M.D. Univ. *Edin.*, Professor of Physiology, University of Sydney, p.r. 'Lincluden,' Fairfax Road, Double Bay. *Vice-President.*
1892		Sturt, Clifton, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 'Wistaria,' Bulli.
1876	P 1	Suttor, The Hon. W. H., M.L.C., 3 Albert-street, Woollahra.
1893		‡Taylor, James, B.Sc., A. R. S. M., Government Metallurgist, Adderton Road, Dundas.

Elected		
1861	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1896		Thom, James Campbell, Solicitor for Railways, 'Camelot,' Forest Road, Bexley.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-street; p.r. 'Berowra,' Beaconsfield-street, Bexley.
1878		Thomas, F. J., Hunter River N.S.N. Co , Sussex-street.
1879		Thomson, Dugald, M.L.A., c/o Messrs. Thomson Bros., 9 Castlereagh-street.
1875		Thompson, Joseph, 159 Brougham-street, Woolloomooloo.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, D.P.H. *Camb.*, M.R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle.
1892		Thow, William, M. Inst. C.E., M. Inst. M.E., Locomotive Department Eveleigh.
1886	P 5	Threlfall, Richard, M.A. *Cantab.*, Professor of Physics, University of Sydney. *Vice-President.*
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1876		Tibbits, Walter Hugh, M.R.C.S. *Eng.*, Gunning.
1896		Tickle, Arthur H., 'Adderton,' Fullerton-street, Woollahra.
1894		Tidswell, Frank, M. B., M. Ch., D.P.H., 'Nugal Lodge,' Milford-st., Randwick.
1876		Toohey, The Hon. J. T., M.L.C., 'Moira,' Burwood.
1891		Tooth, Alfred Erasmus, Union Chambers, 68½ Pitt-street.
1894		Tooth, Arthur W., Australian Club, Bent-street.
1893		Townsend, George W., C.E.
1873	P 1	Trebeck, Prosper N., J.P., 2 O'Connell-street.
1879		Trebeck, P. C., 2 O'Connell-street.
1877		‡Tucker, G. A., Ph. D., c/o Perpetual Trustee Co., 2 Spring-st.
1895		Van de Velde, Clement, C.E., (Diploma University Ghent), Wynyard Buildings, City.
1883		Vause, Arthur John, M.B., C.M. *Edin.*,' BayView House,' Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., viâ Fazio 2, Spezia, Italy.
1896		Verdon, Arthur, Australian Club.
1890		Vicars, James, M.C.E., Assoc. M. Inst. C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1896		Vivian, Walter Hussey, Stock and Share Broker, 100 Pitt-st., p.r. 'The Châlet,' Manly.
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company, 2 Spring-street.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Supervising Engineer, Harbours and Rivers Department, Newcastle.
1896		Walsh, C. R., Prothonotary, Supreme Court.
1895		Ward, James Wenman, 271 Bourke-street.
1891		Ward, Thomas William Chapman, B.A. B.C.E. *Syd.*,' Sainsbury,' The Avenue, Petersham.
1877		Warren, William Edward, B.A., M.D., M. Ch. Queen's University *Irel.*, M.D. *Syd.*, 263 Elizabeth-street, Sydney.

Elected		
1883	P 8	Warren, W. H., Wh. Sc., M. Inst. C.E., Professor of Engineering, University of Sydney.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, 5 Richmond Terrace, Domain.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1859		Watt, Charles, Parramatta.
1876		Waugh, Isaac, M.B., M.D. *Dub.*, T.C.D., Parramatta.
1897		Webb, Fredk. William. C.M.G., J.P., Clerk of the Legislative Assembly, 'Livadia,' Chandos-street, Ashfield.
1866		Webster, A. S., c/o Permanent Trustee Co., 16 O'Connell-st.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Borough Engineer, Town Hall, Marrickville.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1881		‡Wesley, W. H.
1878		Westgarth, G. C., Bond-street, p.r. 59 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Oaklands,' Edgecliff Road.
1892		White, Harold Pogson, Assistant Assayer and Analyst, Dept. of Mines, p.r. 'Chester,' Station-street, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1874		White, Rev. James S., M.A., LL.D. *Syd.*, 'Gowrie,' Singleton.
1888		White, The Hon. Robert Hoddle Driberg, M.L.C., Union Club, p.r. 'Tahlee,' Port Stephens.
1878		Wilkinson, Rev. Samuel, 'Regent House,' Regent-street, Petersham.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 207 Macquarie-street.
1876		Williams, Percy Edward, The Department of Audit; p.r. 'Everley,' Drummoyne-street, Hunter's Hill.
1878		Wilshire, James Thompson, F.L.S., F.R.H.S., J.P., 'Coolooli,' off Ranger's Road, Shell Cove, Neutral Bay.
1879		Wilshire, F. R., P.M., Penrith.
1891		Wilson, Robert Archibald, M.D. *Glas.*, Mast. Surg. *Glas.*, 2 Booth-street, Balmain.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., Waverley.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1881		Wright, Frederick, M.P.S., c/o Messrs. Elliott Bros., Limited, O'Connell-street, p.r. Harnett-street.
1872		Wright, Horatio G. A., M.R.C.S. *Eng.*, L.S.A. *Lond.*, 4 York-st., Wynyard Square. *Hon. Treasurer.*
1893		Wright, John, C.E., Toxteth-street, Glebe Point.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Elected		

Honorary Members.

Limited to Twenty.

M.—Recipients of the Clarke Medal.

1878		Agnew, Sir James, K.C.M.G., M.D., Hon. Secretary, Royal Society of Tasmania, Hobart.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1895		Bunsen, Professor Robert Wilhelm, For. Mem. R.S., Heidelberg.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., late Government Astronomer of Victoria, Melbourne.
1887		Foster, Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Augustus Charles, C.M.G., M.L.C., F.R.G.S., Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M.D., F.R.S., Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., late Director of the Royal Gardens, Kew.
1892		Huggins, William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1875	M	M'Coy, Frederick, C.M.G., D.Sc., F.R.S., F.G.S., Hon. M.C.P.S., C.M.Z.S., Professor of Natural Science in the Melbourne University, Government Palæontologist, and Director of National Museum, Melbourne.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1888	P 3 M	Tate, Ralph, F.G.S., F.L.S., Professor of Natural Science, University, Adelaide, South Australia.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S. Parkstone, Dorset.
1875		Waterhouse, F. G., F.G.S., C.M.Z.S., Adelaide, South Australia.

Corresponding Members.

Limited to Twenty-five.

1886	Marcou, Professor Jules, F.G.S., Cambridge, Mass., United States of America.

Obituary.

1897.

Ordinary Members.

1896	Bridge, John
1890	Eddy, E. M. G.
1876	Eldred, Capt. W. H.
1886	Hutchinson, W. A.
1874	Lloyd, Hon. G. A.
1875	Sahl, Charles L.
1883	Styles, G. M.
1884	Wiesener, T. F.

AWARDS OF THE CLARKE MEDAL.

Established in memory of

THE LATE REVD. W. B. CLARKE, M.A., F.R.S., F.G.S., &c.,

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia.

1878 Professor Sir Richard Owen, K.C.B., F.R.S., Hampton Court.
1879 George Bentham, C.M.G., F R.S., The Royal Gardens, Kew.
1880 Professor Huxley, F.R.S., The Royal School of Mines, London, 4 Marlborough Place, Abbey Road, N.W.
1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.
1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.
1883 Baron Ferdinand von Mueller, K.C.M.G., M.D., PH.D., F.R.S., F.L.S., Government Botanist, Melbourne.
1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., late Director of the Geological Survey of Canada, Ottawa.
1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.
1886 Professor L. G. De Koninck, M.D., University of Liège, Belgium.
1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.
1888 Rev. Julian E. Tenison-Woods, F.G.S., F.L.S., Sydney.
1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., late Government Astronomer of Victoria, Melbourne.
1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.
1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1892 Professor William Turner Thiselton Dyer, C.M.G., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.
1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.
1895 Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Brisbane, Queensland.
1895 Robert Etheridge, Junr., Government Palæontologist, Curator of the Australian Museum, Sydney.
1896 Hon. Augustus Charles Gregory, C.M.G., M.L.C., F.R.G.S., Brisbane.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

The Royal Society of New South Wales offers its Medal and Money Prize for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon various subjects published annually.

Money Prize of £25.

1882 John Fraser, B.A., West Maitland, for paper on 'The Aborigines of New South Wales.'
1882 Andrew Ross, M.D., Molong. for paper on the 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper on 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper on 'The Tin deposits of New South Wales.

1887 Jonathan Seaver, F.G.S., Sydney, for paper on 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper on 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

1889 Thomas Whitelegge, F.R.M.S., Sydney, for 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper on 'The Australian Aborigines.

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper on 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper on 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, for paper on the 'Timbers of New South Wales.

1894 R. H. Mathews, L.S., for paper on 'The Aboriginal Rock Carvings and Paintings in New South Wales.

1895 C. J. Martin, B.Sc., M.B. *Lond.*, for paper on 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).

1896 Rev. J. Milne Curran, Sydney, for paper on "The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found."

Elected		
1889	P 3	Mingaye, John C. H., F.C.S., M.A.I.M.E., Assayer and Analyst to the Department of Mines, Sydney.
1892		Mollison, James Smith, M. Inst. C.E, Roads, Bridges and Sewerage Branch, Department of Public Works, Sydney.
1856	P 7	Moore, Charles, F.L S , Australian Club, p.r. 4 Queen-street, Woollahra. *Vice-President.*
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1893		Money, Angel, M.D., F.R.C.P. *Lond.*, 75 Hunter-street.
1877	P 1	Morris, William, Fel. Fac. Phys. and Surg. *Glas.*, F.R.M.S. *Lond.*, 5 Bligh-street.
1882		Moss. Sydney, 'Kaloola,' Kiribilli Point, North Shore.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd.*, 'Killountan,' Challis Avenue, Pott's Point.
1888		Mullins, George Lane, M.A., M D. Trin. Coll. *Dub.*, M.D. *Syd.*, F.R M.S. *Lond.*, Clarendon Terrace, Elizabeth-street.
1887		Munro, William John, M.B., C.M. *Edin.*, M.R.C.S. *Eng.*, 112 Glebe Road, Glebe.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1890		Neill, Leopold Edward Flood, M.B., Ch.M. Univ. *Syd.*, No. 3 Bayswater Houses, Double Bay.
1891		Noble, Ewald George, 60 Louisa Road, Longnose Point, Balmain.
1873		Norton, The Hon. James, M.L.C., LL.D., Solicitor, 2 O'Connell-street, p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., 'Waima,' Wentworth Road, Point Piper, Sydney.
1878		Ogilvy, James L., Melbourne Club, Melbourne.
1888		O'Neill, G. Lamb, M.B., C.M. *Edin.*, 291 Elizabeth-street.
1896		Onslow, Major James William Macarthur, Camden Park, Menangle.
1883		Oram, Arthur Murray, M.D. Univ. *Edin.*, 213 Macquarie-street, North.
1875		O'Reilly, W. W. J., M.D., M.Ch., Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street.
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A. F., Assoc. M. Inst. C.E., Roads and Bridges Office, Cowra.
1893		Owen, Lieut. Percy Thomas, Assistant Engineer, Military Works, Australian Club.
1875		Palmer, J. H., 'Hinton,' Queen-street, Burwood.
1880		Palmer, Joseph, 133 Pitt-st., p.r. Kenneth-st., Willoughby.
1878		Paterson, Alexander, M.D., M.A. *Edin.*, 146 Crystal-street, Petersham.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1877		Pedley, Perceval R., 227 Macquarie-street.

Elected		
1877		Perkins, Henry A., ' Barangah,' Coventry Road, Homebush.
1881		Philip, Alex., L.K.Q.C.P. *Irel.*, L.R.C.S. *Irel.*, 574 Crown-street, Surry Hills.
1876		Pickburn, Thomas, M.D., C.M. *Aberdeen*, M.R.C.S. *Eng.*, 22 College-street.
1879	P 4	Pittman, Edward F., Assoc. R.S.M., L.S., Government Geologist, Department of Mines, 39 Pitt-street.
1881		Poate, Frederick, District Surveyor, Tamworth.
1890		Pockley, Francis Antill, M.B., M C. Univ. *Edin.*, M.R.C.S. *Eng.*, 227 Macquarie-street.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887		Pollock, James Arthur, B.E. Roy. Univ. *Irel.*, B.Sc. *Syd.*, Demonstrator in Physics, Sydney University.
1891		Poole, William Jr., Assoc. M. Inst. C.E., 87 Pitt-street, Redfern.
1896		Pope, Roland James, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 261 Elizabeth-street.
1882	P 4	Porter, Donald, Tamworth.
1891		Pringle, Adam Thompson, Government Inspector of Vineyards, 'Albma Villa,' Parramatta Road, Concord.
1893		Purser, Cecil, B.A., M.B., Ch. M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1876		Quaife, Frederick H., M.A., M.D., Master of Surgery *Glas.*, 'Hughenden,' 19 Queen-street, Woollahra.
1865	P 1	‡Ramsay, Edward P., LL.D Univ. St. And. *Aberdeen*, F.R.S.E., F.L.S., Lincoln Grove, Kingswood, Western Railway.
1868		Reading, E., Mem. Odont. Soc. *Lond.*, Elizabeth-street, Hyde Park, p.r. Fullerton-street, Woollahra.
1888		Reading, Richard Fairfax, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.D.S. *Eng.*, 151 Macquarie-street.
1881	P 3	Rennie, Edward H., M.A. *Syd.*, D.Sc. *Lond.*, Professor of Chemistry, University, Adelaide.
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 16 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, M.L.C., B.A. *Syd.*, M.D., F.R.C.S. *Edin.*, 295 Elizabeth-street.
1868	P 4	Roberts, Sir Alfred, M.R.C.S. *Eng.*, Hon. Mem. Zool. and Bot. Soc. *Vienna*, 125 Macquarie-street North.
1893	P 1	Roberts, W. S. de Lisle, C.E., Sewerage Branch, Public Works Department, Phillip-street.
1885		Rolleston, John C., C.E., Harbours and Rivers Branch, Dept. of Public Works.
1892		Rossback, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, Hospital for the Insane, ' Kenmore,' near Goulburn.
1895		Ross, Colin John, B Sc., B E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895		Ross, Herbert E., Consulting Mining Engineer, 121 Pitt-st.
1865		Ross, J. Grafton, O'Connell-street.

Elected		
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-st., and Union Club.
1894		Rowney, George Henry, Assoc. M. Inst. C.E., Water and Sewerage Board, Pitt-street, p.r. 12 Kellet-street, Darlinghurst.
1864	P 59	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F.R. Met. Soc., Hon. Memb. Roy. Soc., South Australia, Government Astronomer, Sydney Observatory.
1883		Rygate, Phillip W., M.A., B.E. *Syd.*, 98 Pitt-street.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., Sydney University, Glebe.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1886		Scott, Walter, M.A. *Oxon.*, Professor of Greek, University, Sydney.
1891		Seaver, Thomas Whitchurch, B.C.E. Roy. Univ. *Irel.*, Water Conservation Branch, Public Works Department, p.r. Undercliffe-street, North Shore.
1877	P 1	Selfe, Norman, M. Inst. C.E., M. Inst. M.E., Victoria Chambers, 279 George-street.
1890	P 1	Sellors, R. P., B.A. *Syd.*, F.R.A.S., Sydney Observatory.
1891		Selman, D. Codrington, Wh. Sc., St. James's Chambers, King-st., City.
1891		Shaw, Percy William, C.E., 'Leswell,' Torrington Road, Strathfield.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Divisional Engineer, Railway Department, Goulburn.
1879		Shepard, A. D., Box 728 G.P.O. Sydney.
1875		Sheppard, Rev. G., B.A. *Syd.*, Berrima.
1882		Shewen, Alfred, M.D. Univ. *Lond.*, M.R.C.S. *Eng.*, 6 Lyons' Terrace, Hyde Park.
1894		Simpson, Benjamin Crispin, M. Inst. C.E., 113 Phillip-street.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Hospital for the Insane, Gladesville.
1893		Sinclair, Russell, M.I.M.E. &c., Consulting Engineer, 97 Pitt-st.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1877		Sloper, Frederick Evans, 94 Oxford-street, Paddington.
1891	P 1	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 3	Smeeth, William Frederick, M.A., B.E., F.G.S., A.R.S.M., Demonstrator in Geology, Sydney University, p.r. 6 Arthur-st., North Shore
1893	P 10	Smith, Henry G., F.C.S., Mineralogist, Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie. Denison-street, Woollahra.
1875		Smith, Robert, M.A. *Syd.*, Marlborough Chambers, 2 O'Connell-street.
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department, N. Sydney.
1896		Smyth, Selwood, Harbours and Rivers Branch, Public Works Department.
1892		Speak, Savannah J., Assoc. R.S.M.
1896		Spencer, Walter, M.D. *Brux.*, 23 Edgeware Road, Enmore.

Elected		
1893		Spencer, Thomas William Loraine, Resident Engineer, Roads and Bridges, Armidale.
1879		Spry, James Monsell, Union Club.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E., 'Fenella,' Frederick-street, Rockdale.
1892		Statham, Hugh Worthington, Roads Office, Blayney.
1882		Steel, John, L.R.C.P., L.R.C.S. *Edin.*, Ch. M. B.S., Univ. *Melb.*, 3 Lyons' Terrace, Hyde Park.
1889		Stephen, Arthur Winbourn, L.S., Mulgoa.
1879		‡Stephen, The Hon. Septimus A., M.L C., 12—14 O'Connell-st.
1891		Stilwell, A. W., Assoc. M. Inst. C.E., 'Strathroy,' East Orange.
1892		Stuart, Charles McDonnell, B.E. Queen's Univ. *Irel.*, M. Inst. C.E., 'Dunsevirick,' Pymble.
1883	P 3	Stuart, T. P. Anderson, M D. Univ. *Edin.*, Professor of Physiology, University of Sydney, p.r. 'Lincluden,' Fairfax Road, Double Bay. *Vice-President.*
1892		Sturt, Clifton, L.R.C.P., L.R.C S. *Edin.*, L.F.P.S. *Glas.*, 'Wistari,' Bulli.
1887		Sulman, John, F.R.I.B.A., 339 George-street.
1876	P 1	Suttor, The Hon. W. H., M.L.C., 3 Albert-street, Woollahra.
1893		‡Taylor, James, B. Sc., A.R.S.M., Government Metallurgist, Adderton Road, Dundas.
1862	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1896		Thom, James Campbell, Solicitor for Railways, 'Camelot,' Forest Road, Bexley.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-street; p.r. 'Berowra,' Beaconsfield-street, Bexley.
1878		Thomas, F. J., Hunter River N.S.N. Co., Sussex-street.
1879		Thomson, Dugald, M.L.A., c/o Messrs. Thomson Bros., 9 Castlereagh-street.
1875		Thompson, Joseph, 159 Brougham-street, Woolloomooloo.
1877		Thompson, Thomas James, Eldon Chambers, 92 Pitt-street.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, Health Department, 127 Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle.
1892		Thow, William, M. Inst. C.E., Locomotive Department, Eveleigh.
1886	P 4	Threlfall, Richard, M.A. *Cantab.*, Professor of Physics, University of Sydney. *Vice-President.*
1888		Thring, Edward T., F R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1876		Tibbits, Walter Hugh, M.R.C.S. *Eng.*, Gunning.
1896		Tickle, Arthur H., 'Adderton,' Fullerton-street, Woollahra.
1894		Tidswell, Frank, M. B., M. Ch., 'Nugal Lodge,' Milford-street, Randwick.
1876		Toohey, The Hon. J. T., M.L.C., 'Moira,' Burwood.
1891		Tooth, Alfred Erasmus, Union Chambers, 68½ Pitt-street.
1894		Tooth, Arthur W., Australian Club. Bent-street.
1893		Townsend, George W., C.E.
1873	P 1	Trebeck, Prosper N., J.P., 2 O'Connell-street.
1879		Trebeck, P. C., 2 O'Connell-street.
1877		‡Tucker, G. A , Ph. D., c/o Perpetual Trustee Co., 2 Spring-street.

Elected		
1895		Van de Velde, Clement, C.E., (Diploma University Ghent), Wynyard Buildings, City.
1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'Bay View House,' Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., viâ Fazio 2, Spezia, Italy.
1896		Verdon, Arthur, Australian Club.
1890		Vicars, James, M.C.E., Assoc. M. Inst. C.E., City Surveyor, Adelaide.
1892		Vickery, George B., 78 Pitt-street.
1896		Vivian, Walter Hussey, Stock and Share Broker, 'The Châlet,' Manly.
1876		Voss, Houlton H., J.P.. c/o Perpetual Trustee Company, 2 Spring-street.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Supervising Engineer, Harbours and Rivers Department, Newcastle.
1896		Walsh, C. R., Prothonotary, Supreme Court.
1895		Ward, James Wenman, 271 Bourke-street.
1867		Ward, R. D., M.R.C.S. *Eng.*, West-street, St. Leonards.
1891		Ward, Thomas William Chapman, B.A., B.C.E. *Syd.*, 'Sainsbury' The Avenue, Petersham.
1883		Waddell, W. W., F.R.I.B.A., M. Inst. C.E., 'Upton Grange,' St. Leonards.
1877		Warren, William Edward, M.D., M. Ch. Queen's University *Irel.*, 263 Elizabeth-street, Sydney.
1883	P 5	Warren, W. H., Wh. Sc, M. Inst. C.E., Professor of Engineering, University of Sydney; p.r. 'Undoona,' Albert Road, Strathfield.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman. Attorney General's Department, Macquarie-st.
1891		Watkins, Sydney C., M.R.C.S. *Eng.*, Manly.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1859		Watt, Charles, Parramatta.
1876		Waugh, Isaac, M.B., M.C. *Dub.*, T.C.D., Parramatta.
1866		Webster, A. S., c/o Permanent Trustee Co., 16 O'Connell-st.
1892		Webster, James Philip, Assoc. M. Inst. C.E., L.S., *New Zealand*, Borough Engineer, Town Hall, Marrickville.
1867		Weigall, Albert Bythesea, B.A. *Oxon.*, M.A. *Syd.*, Head Master of the Sydney Grammar School, College-street.
1881		‡Wesley. W. H.
1878		Westgarth, G. C., Bond-street, p.r. 59 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Oaklands,' Edgecliff Road.
1892		White, Harold Pogson, Assistant Assayer and Analyst, Dept. of Mines, p.r. 'Chester,' Station-street, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1874		White, Rev. James S., M.A., LL.D. *Syd.*, 'Gowrie,' Singleton.
1888		White, The Hon. Robert Hoddle Driberg, M.L.C., Union Club, p.r. 'Tahlee,' Port Stephens.
1884		Wiesener, T. F., 334 George-street.
1878		Wilkinson, Rev. Samuel, 'Regent House,' Regent-street, Petersham.
1883		Wilkinson, W. Camac, M D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 207 Macquarie-street.

Elected		
1876		Williams, Percy Edward, The Treasury, p.r. 'Labrena,' Hunter's Hill.
1878		Wilshire, James Thompson, F.L.S., F.R.H.S., J.P., 'Coolooli,' off Ranger's Road, Shell Cove, Neutral Bay.
1879		Wilshire, F. R , P.M., Berrima.
1891		Wilson, Robert Archibald, M.D. *Glas.*, Mast. Surg. *Glas.*, 2 Booth-street, Balmain.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 'Beverley,' 15 Mansfield-st., Glebe Point.
1891		Wood, Percy Moore, L.R.C.P. *Lond* , M.R.C S. *Eng.*, 'Redcliffe," Liverpool Road, Ashfield.
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1881		Wright, Frederick, M P.S., c/o Messrs. Elliott Bros., Limited, O'Connell-street, p.r. Harnett-street.
1872		Wright, Horatio G. A., M.R.C.S. *Eng.*, L S.A. *Lond.*, 4 York-st., Wynyard Square. *Hon Treasurer.*
1893		Wright, John, C.E., Toxteth-street, Glebe Point.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Honorary Members.

Limited to Twenty.

M.—Recipients of the Clarke Medal.

1878		Agnew, Sir James, M.D., Hon. Secretary, Royal Society of Tasmania, Hobart.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1895		Bunsen, Professor Robert Wilhelm, For. Mem. R.S., Heidelberg.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., late Government Astronomer of Victoria, Melbourne.
1887		Foster, Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Augustus Charles, C.M.G., M.L.C., F.R.G.S., Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M D., F.R.S., Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., late Director of the Royal Gardens, Kew.
1892		Huggins, William, D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1875	M	M'Coy, Frederick, C.M.G., D.Sc., F.R.S., F.G.S., Hon. M.C.P.S., C.M.Z.S., Professor of Natural Science in the Melbourne University, Government Palæontologist, and Director of National Museum, Melbourne.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1888	P 2 M	Tate, Ralph, F.G.S., F.L.S., Professor of Natural Science, University, Adelaide, South Australia.

Elected

1895 Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Parkstone, Dorset.

1875 Waterhouse, F. G., F.G.S., C.M.Z.S., Adelaide, South Australia.

Corresponding Members.

Limited to Twenty-five.

1886 Marcou, Professor Jules, F.G.S., Cambridge, Mass., United States of America.

Obituary.

1896.

Honorary Member.

1875 Mueller, Baron Ferdinand von, K.C.M.G., M.D., F.R.S., F.L.S.

Ordinary Members.

1882 Chambers, F.R.C.P., F.R.C.S. *Edin.*
1877 Garvan, J. P., M.L.A.
1884 Gill, Rev. W. Wyatt, B.A., LL.D.
1895 Nicholls, W. H.

1897.

1876 Eldred, Capt. W. H.
1875 Sahl, Charles L.
1883 Styles, G. M.

AWARDS OF THE CLARKE MEDAL.

Established in memory of
The late Revd. W. B. CLARKE, M.A., F.R.S., F.G.S., &c.,
Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia.

1878 Professor Sir Richard Owen, K.C.B., F.R.S., Hampton Court.
1879 George Bentham, C.M.G., F.R.S., The Royal Gardens, Kew.
1880 Professor Huxley, F.R.S., The Royal School of Mines, London, 4 Marlborough Place, Abbey Road, N.W.
1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.
1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.
1883 Baron Ferdinand von Mueller, K.C.M.G , M.D., PH.D., F.R.S., F.L.S., Government Botanist, Melbourne.
1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada, Ottawa.
1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.
1886 Professor L. G. De Koninck, M.D., University of Liége, Belgium.
1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.
1888 Rev. Julian E. Tenison-Woods, F.G.S., F.L.S., Sydney.

1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., late Government Astronomer of Victoria, Melbourne.
1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.
1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1892 Professor William Turner Thiselton Dyer, C.M.G., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.
1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.
1895 Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Brisbane, Queensland.
1895 Robert Etheridge, Junr., Government Palæontologist, Department of Mines, Sydney.
1896 Hon. Augustus Charles Gregory, C.M.G., M.L.C., F.R.G.S., Brisbane.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

The Royal Society of New South Wales offers its Medal and Money Prize for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon various subjects published annually.

Money Prize of £25.

1882 John Fraser, B.A., West Maitland, for paper on 'The Aborigines of New South Wales.'
1882 Andrew Ross, M.D., Molong, for paper on the 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper on 'Water supply in the Interior of New South Wales.'
1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper on 'The Tin deposits of New South Wales.
1887 Jonathan Seaver, F.G.S., Sydney, for paper on 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.
1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper on 'The Anatomy and Life-history of Mollusca peculiar to Australia.'
1889 Thomas Whitelegge, F.R.M.S., Sydney, for 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.
1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper on 'The Australian Aborigines.
1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper on 'The Microscopic Structure of Australian Rocks.'
1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper on 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'
1894 J. V. De Coque, for paper on the 'Timbers of New South Wales.
1894 R. H. Mathews, L.S., for paper on 'The Aboriginal Rock Carvings and Paintings in New South Wales.
1895 C. J. Martin, B.Sc., M.B. *Lond.*, for paper on 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).
1896 Rev. J. Milne Curran, Sydney, for paper on "The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found."

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES,

EDITED BY

THE HONORARY SECRETARIES.

THE AUTHORS OF PAPERS ARE ALONE RESPONSIBLE FOR THE OPINIONS EXPRESSED THEREIN.

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1897.

ANNIVERSARY ADDRESS.

By T. W. Edgeworth David, B.A., F.G.S.,

Professor of Geology in the University of Sydney.

[With Plates I.–IV.]

[*Read before the Royal Society of N. S. Wales, May 20, 1896.*]

The privilege having been accorded me by you of addressing you on this the Seventy-fifth Anniversary of the existence of our Society, I propose in conformity with a custom followed by many of my predecessors, to arrange my address under three heads:

(1) Matters which have directly affected the Society during the past twelve months.

(2) Brief review of scientific, medical and engineering work in New South Wales, chiefly during the above period, etc., etc.

(3) Summary of the present state of our knowledge as to the structure and origin of the Blue Mountains.

I. The Royal Society of New South Wales.

In the first place it is my pleasing duty to announce that His Excellency Viscount Hampden has graciously consented to accept the office of Patron of this Society, and has thereby signified his intention of taking that kindly interest in our welfare which has from time to time been shown by his Viceregal predecessors.

It will doubtless be remembered that Prof. Threlfall in his Presidential Address last year, stated that the Society's present premises were becoming too small for the accommodation of the Library, and that, notwithstanding that temporary relief had been found in various ways, the time was not far distant when the Building Fund would have to be expended in providing the actual space required. The Council have been so deeply convinced of the necessity of securing more space accommodation, that they have purchased additional land, and after much consideration

have designed and carried out the various additions and alterations which you see to-night, and I trust that the members will appreciate the efforts that have been made to increase their comfort and convenience in the matter of enlarged rooms, lavatory, and out-buildings.

Roll of Members.—The number of members on the roll on the 30th April, 1895, was four hundred and twenty. Twelve new members have been elected, and one has been restored to the roll. The Society has lost by resignations fifteen members, through default in payment of subscriptions two, and by death seven, so that the total number on the roll on the 30th April, 1896, was four hundred and nine.

Obituary.—The following is a list of the members who have died since our last annual meeting:—

Honorary Members:

Cockle, Sir James, F.R.S., Elected 1876.
Huxley, Rt. Hon. Prof., P.C., F.R.S., Elected 1879.
Pasteur, Louis. M.D., Elected 1879.

Corresponding Member:

Clark, Hyde, V.P. Anthrop. Inst., Elected 1880.

Ordinary Members:

Campbell, Dr. Allan, Elected 1876.
Dight, Arthur, Elected 1876.
McGillivray, Dr. P. N., Elected 1882.
Olliff, A. S., Elected 1890.
Sager, E. E., Elected 1886.
Sedgwick, Dr. W. G., Elected 1876.
Sutherland, Dr. G. W., Elected 1891.

The death of Thomas Henry Huxley has removed one of the most distinguished of modern biologists, one who yielded to none in literary and critical ability as a scientific writer.

He was born at Ealing on May 4th, 1825, and was for some time educated at the school in his native place, where his father was one of the masters. He then studied German scientific

literature and medicine, reading privately. Subsequently he attended lectures at the Medical School, Charing Cross Hospital, taking his degree of M.B. in 1845 with honours in physiology.

In 1846 he was appointed Assistant-Surgeon to H.M.S. "Victory," and a few months later he accepted the position of Assistant-Surgeon to H.M.S. "Rattlesnake." The voyage lasted from 1847 to 1850, during part of which time Huxley was stationed on the east coast of Australia, his ship being engaged in a survey of the passage between the Barrier Reef and the main land, and of the sea between the northern extremity of the Barrier Reef and New Guinea. It was here that he commenced that series of zoological studies which were soon destined to make him so famous. The results of his researches during this three years' voyage were published by the Linnean and Royal Societies, and a year after his return to England, in 1851, when he was barely twenty-six years of age, he was elected a Fellow of the Royal Society.

In 1854 he became Professor of Natural History including Palæontology at the Royal School of Mines, and Curator of the Fossil Collections at the Museum of Geology at Jermyn-street, also Tullerian Professor of Physiology and Comparative Anatomy to the University of London. In 1858 he was appointed Croonian Lecturer to the Royal Society, when he delivered his celebrated address on "The Theory of the Vertebrate Skull." During 1860 Huxley delivered his course of lectures on "The Relation of Man to the Lower Animals." In 1862, 1869, and 1870 he delivered three presidential addresses to the Geological Society of London. From 1863 to 1870 he was Hunterian Professor of Comparative Anatomy in the Royal College of Surgeons, and in 1869-70 was President of the Ethnological Society.

He was Secretary to the Royal Society from 1871-1880, and President from 1883-85. In 1876 he delivered several lectures in America. In 1885 failing health compelled him to retire, and he resigned all his appointments except that of Dean and Honorary Professor of Biology in the Royal College of Science, South Ken-

sington, which appointment he held at the time of his death. He was made a member of the Privy Council in 1892.

Of his published works, the following may be specially mentioned :—"Oceanic Hydrozoa," "Lessons in Elementary Physiology," "Introduction to the Classification of Animals," "Lay Sermons, Addresses, and Reviews," "Anatomy of the Vertebrata," "Anatomy of the Invertebrata," "Practical Biology," "Man's Place in Nature," "The Crayfish," "Physiography."

Of the one hundred and fourty-four papers contributed by him, two relate specially to Australian subjects, viz. :—"On some Amphibian and Reptilian Remains from South Africa and Australia,"[1] and "On the Premolar Teeth of *Diprotodon*."[2] In recognition of this work our Society conferred upon him the Clarke Memorial Medal in 1880.

Memorable as have been the services which he has rendered to biology, he will perhaps be held in memory by the world at large as the man who taught the doctrine of Darwin in a tongue that the people understood. A master of English prose, unrivalled as a lecturer and debater, and earnest in the pursuit of truth, he proved himself on all occasions a most formidable controversialist, but he did not forget while he warred down the proud to spare the vanquished, and consequently though many fought him it may be doubted whether he had any true foes. I trust I may be allowed to quote in conclusion the following from the *Pall Mall Gazette* :—"Four kings laboured to build a mighty hall, the Hall of a Hundred Columns at Karnak. In a century they built it, and they died ; but the hall remains. Four men (Darwin, Tyndall, Huxley, Spencer) more than all others have raised up within this century an edifice which is the crowning glory of British science, and before the century closes three of them are dead ; but the edifice stands and will stand, as a lasting monument to the power of truth and fearless investigation."

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[1] Quart. Journ. Geol. Soc., 1859. [2] Quart. Journ. Geol. Soc., 1862.

Dr. Louis Pasteur.—By the death of Pasteur not only has France lost the greatest of her citizens, but the world has lost one of its greatest scientific discoverers and benefactors. He died at his country house near St. Cloud, on September 29, 1895, at the age of seventy-three. He was born at Dôle in the Jura. His father was a tanner, who in his earlier days had served with distinction as a soldier.

Pasteur commenced his studies at the Communal College, and thence proceeded to the College of Besançon and to the Ecole Normale, studying specially chemistry and molecular physics, particularly in relation to the formation of crystals. In 1847 he took his degree of Doctor of Science, and later was appointed Professor of Chemical Physics in the University of Strassburg. In 1854 he was made Dean of the Faculty of Sciences at Lille and it was there that he commenced his celebrated researches on fermentation, which proved that fermentation and putrefaction were distinctly due to the action of micro-organisms on organic or inorganic compounds. These researches led him to investigate the diseases of the silk-worm. According to the account published in *Nature*, October 3rd, 1895, p. 551, "for four years he spent several months of each year in tracing the germs of the "febrine" disease through the various stages of development of the worm, egg, larva, chrysalis, and moth. He found what he described as "corpuscles," which he indicated were the contagious elements of the disease. These were taken up from the mulberry leaves on which they had previously been deposited by diseased moths; some of the worms died, but others went on to the chrysalis and even to the moth stage, still affected by these "corpuscles," and the eggs laid by these moths were also found to contain them. He was convinced that the only way was to breed from moths not affected by the disease and to this end he invented the plan which has been universally adopted, and has restored a source of wealth to the silk districts: each female moth, when ready to lay eggs, is placed on a separate piece of linen, on which it may lay them all; after it has laid them and has died, it is dried and then

pounded in water, and the water is then examined microscopically. If "corpuscles" are found in it, the whole of the eggs of this moth and the linen on which they are laid are burnt; if no corpuscles are found, the eggs are kept to be, in due time, hatched and yield healthy silkworms."

Later came Pasteur's great discovery, that a vaccinating virus could be formed by attenuating solutions containing specific bacilli. Thus a mild form of the disease being communicated to the animals vaccinated with such virus, they were rendered immune from the attacks of the non-attenuated organism. This method was subsequently proved by him to be a remedy for fowl cholera, swine erisipelas, and anthrax. It will be within the memory of most of us, that when the Government of New South Wales offered a prize of £25,000 for a satisfactory scheme for the extermination of the rabbit, Pasteur claimed that such an end might be gained by inoculating the rabbits with the microbes of fowl-cholera. Exhaustive experiments at Rodd Island conducted by Pasteur's pupil, Dr. Loir, and by Dr. Katz, seemed to show that the disease was not very infectious in the case of rabbits, and as it was uncertain that it was readily communicable from one rabbit to another, but certain that it would cause great mortality among the Australian birds Pasteur's proposal was not accepted. This country, however, together with the whole civilized world, owes Pasteur a deep debt of gratitude, not only for his own discoveries, brilliant and numerous as they have been, but also for those which have resulted directly from his teaching. Working on the same lines of research as those pursued by Pasteur, Héricourt and Richet made the very important discovery that the fluids and cells of animals which have been rendered immune by vaccination have themselves become vaccines and are capable of protecting also other animals. Serum-therapy is based on this principle, and Professor Anderson Stuart[1] estimates that the number of human lives saved in New South Wales alone by

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1 Antitoxic Serum for the Cure of Diphtheria.—Report by Board of Health, by Authority, Sydney, 1895, p. 1.

the use of the antitoxic serum for the cure of diphtheria, amounts to about two hundred per annum. In the days of ancient Rome one of the highest rewards a citizen could win was the crown with its glorious motto "*Ob civem, servatum.*" Of all the citizens who have deserved such a crown there surely have been none better deserving than Pasteur.

Of our ordinary members who died last year Mr. A. S. OLLIFF was well known to many of us, and his death at the early age of thirty, has removed from our band of Australian scientific workers a young entomologist of much promise. He first came to Australia in 1885 to fill the appointment of Assistant Zoologist, in the Branch of Entomology at the Australian Museum. In 1890 he received the appointment of Entomologist to the Department of Agriculture in New South Wales. He died on December 29th. His scientific papers relating chiefly to the Lepidoptera and Coleoptera were published for the most part in the Proceedings of the Linnean Society of New South Wales.

Dr. P. H. MACGILLIVRAY of Victoria, while practising his profession found leisure to do a large amount of useful work on the Australian Polyzoa. Most of his work on the Polyzoa is to be found in the Transactions of the Royal Society of Victoria, in the Decades of Sir Frederick McCoy, and in his own "Monograph on the tertiary Polyzoa of Victoria."

Papers read in 1895.—During the past year the Society held eight meetings, at which the average attendance of members was thirty-eight, and of visitors 3·5, the following twenty-six papers were read :—

1. "President's Address," by R. THRELFALL, M.A., Professor of Physics in the University of Sydney.
2. "A contribution to the Chemistry of Australian Myrtaceous Kinos," by J. H. MAIDEN, F.L.S., and H. G. SMITH.
3. "Paper on Aeronautical Work," by LAWRENCE HARGRAVE.
4. "Notes on two New Mineral Substances from the Australian Broken Hill Consols Mine," by E. F. PITTMAN, A.R.S.M., Government Geologist, Sydney.

5. "The Cubic Parabola as applied to the Easing of Circular Curves on Railway Lines," by C. J. MERFIELD, (Communicated by Mr. G. H. Knibbs).
6. "The History, Theory, and Determination of the Viscosity of Water by the Efflux Method," by G. H. KNIBBS, Lecturer on Surveying, University of Sydney.
7. "On the Physiological Action of the Venom of the Australian Black Snake *(Pseudechis porphyriacus)*, by C. J. MARTIN, B.Sc., M.B., *Lond.*
8. "Considerations on the Surviving Refugees in Austral Lands of Ancient Antarctic Life," by C. HEDLEY, F.L.S., Assistant in Zoology to the Australian Museum.
9. "Icebergs in the Southern Ocean," by H. C. RUSSELL, B.A., C.M.G., F.R.S., &c.
10. "On some New South Wales and other Minerals, Note No. 7," by A. LIVERSIDGE, M.A., F.R.S., Professor of Chemistry in the University of Sydney.
11. "On a Natural Deposit of Aluminium Succinate in the Timber of *Grevillea robusta*, R. Br.," by J. H. MAIDEN and H. G. SMITH.
12. "On the amount of Gold and Silver in Sea-Water," by A. LIVERSIDGE, M.A., F.R.S., Professor of Chemistry in the University of Sydney, New South Wales.
13. "The removal of Silver and Gold from Sea-water by Muntz Metal Sheathing," by A. LIVERSIDGE, M.A., F.R.S., Professor of Chemistry, University of Sydney, N. S. Wales.
14. "Some Folk-Songs and Myths from Samoa," by JOHN FRASER, LL.D.
15. "Contributions to a knowledge of Australian Vegetable Exudations, No. 1," by J. H. MAIDEN, F.L.S., and HENRY G. SMITH.
16. "Geological Laboratory Notes, (Note No. 1)," by the Rev. J. MILNE CURRAN.
17. "On the occurrence of Artesian water in rocks other than the Cretaceous," by E. F. PITTMAN, A.R.S.M.

18. "Note on the Origin of Malachite; observations made in an abandoned Copper Mine" by EDGAR HALL. (Communicated by Professor LIVERSIDGE.)
19. "A comparison of the Languages of Ponape and Hawaii," by the late Rev. E. T. DOANE; with additional notes and illustrations by SIDNEY H. RAY, Memb. Anthrop. Inst. Lond.
20. "The Tensile and Compressive Strength of Magnesium," by S. H. BARRACLOUGH, B.E., M.M.E.
21. "Note on some products from the Fruit of *Pittosporum undulatum* and from the leaves of the Pepper Tree (*Schinus molle*), by R. THRELFALL, M.A., Professor of Physics in the University of Sydney.
22. "Notes on Antarctica Rocks collected by Mr. C. E. Borchgrevink," by Prof. T. W. E. DAVID, B.A., F.G.S., W. F. SMEETH, M.A., A.R.S.M., and J. A. SCHOFIELD, F.C.S., A.R.S.M.
23. "Notes on the Rainfall of the Southern Riverina, 1872 to 1894," by H. C. KIDDLE, F. R. Met. Soc.
24. "The Great Meteor of May 7th, 1895," by H. C. RUSSELL, B.A., C.M.G., F.R.S.
25. "The Climate of Lord Howe Island," by H. C. RUSSELL, B.A., C.M.G., F.R.S.
26. "Types of Australian Weather," by HENRY A. HUNT, Second Meteorological Assistant, Sydney Observatory.

Sectional Meetings.—The Engineering Section held eight meetings at which six papers were read and discussed, the average attendance of members and visitors being twenty-six.

The Medical Section held three meetings, at which five papers were read and numerous exhibits shown.

Financial Position.—From a perusal of the Hon. Treasurer's Financial Statement it will be seen that the Society has paid its way and carried forward a balance of £46 19s. 3d.

The amount which stood to the credit of the Building and Investment Fund at the commencement of the year, viz., £1286 0s. 1d., has been almost absorbed by the purchase of fourteen feet of

land adjoining the Society's premises, having the same depth, viz., eighty feet eight inches.

Clarke Memorial Fund.—The Clarke Memorial Fund amounts to £367 18s., which has been placed at fixed deposit.

Abercromby Fund.—The Abercromby Fund is now closed.

Library.—The amount expended upon the Library has been principally for the periodicals and magazines regularly subscribed to, but the following publications are also included:—"American Journal of Electrical Engineers," Vols. I - IX., "Annals of British Geology," Vols. I – IV.

Exchanges.—Last year we exchanged our Journal with four hundred kindred Societies, receiving in return three hundred and seventeen volumes, one thousand five hundred and forty-six parts, ninety-seven reports, two hundred and six pamphlets, thirty-five hydrographic charts, nineteen meteorological charts, and one astronomical chart,—a total of two thousand two hundred and twenty-one publications.

The following Institutions have been added to the exchange list:—Institution of Mechanical Engineers (London), American Society of Civil Engineers (New York), Royal Society of Sciences (Upsala), University of California (Berkeley), The Hawkesbury Agricultural College (Richmond), The Editor of the Revue de l'Aeronautique (Paris). The two first institutions have presented to the Library their publications from the year 1876 to date.

Honorary Members.—At the General Monthly Meeting of the Society, held July 3 last, on the recommendation of the Council Prof. Robert Wilhelm Bunsen, For. Mem. R.S., Heidelberg, and Dr. Alfred Russel Wallace, F.R.S., &c., Parkstone, Dorset, were unanimously elected Honorary Members of the Society.

Original Researches.—In response to the offer of the Society's medal and a grant of £25 for the best original paper on the following subjects, viz. :—

Series XIV.—*To be sent in not later than May 1, 1895.*

No. 46—On the Silver Ore Deposits of New South Wales.

No. 47—On the Physiological Action of the Poison of any Australian Snake, Spider, or Tick.

No. 48—On the Chemistry of the Australian Gums and Resins.

No paper was sent in on subject No. 46. One was sent in on No. 47 and one on No. 48.

At the meeting held June 26, the Council awarded the prize of £25 and the Society's medal to the writer of the following paper: "On the physiological action of the venom of the Australian black-snake *(Pseudechis porphyriacus)*," by "Bedenke was, noch mehr bedenke wie," C. J. Martin, B.Sc., M.B. *Lond.*, M.R.C.S. *Lond.*

The list of subjects now offered for prizes is as follows:—

The Royal Society of New South Wales offers its medal and £25 for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon each of the subjects, Nos. 49 to 54 inclusive; and for No. 55 the Society offers its medal and ten guineas.

Series XV.—*To be sent in not later than May 1, 1896.*

No. 49—On the origin of Multiple Hydatids in Man.

No. 50—On the occurrence of Precious Stones in New South Wales, with a description of the deposits in which they are found.

No. 51—On the effect of the Australian Climate on the Physical Development of the Australian-born Population.

Series XVI.—*To be sent in not later than May 1, 1897.*

No. 52—On the Embryology and Development of the Echidna or Platypus.

No. 53—The Chemical Composition of the Products from the so-called Kerosene Shale of New South Wales.

No. 54—On the Mode of Occurrence, Chemical Composition, and Origin of Artesian Water in New South Wales.

Series XVII.—*To be sent in not later than May 1, 1898.*

No. 55—On the Iron-ore deposits of New South Wales.

II. Brief Review of Scientific, Medical and Engineering Work etc., done chiefly in New South Wales since the last Annual General Meeting.

Agriculture.—Mr. F. B. Guthrie, F.C.S., has been engaged during the past twelve months at the laboratory of the Agricultural Department chiefly on the following work :—

(*a*) Routine work.—Advice to farmers as to the best methods of treatment of their land, and the most suitable crops, based on analytical examination of the soil. Advice on all matters connected with agricultural chemistry, including analyses of fertilizers and farm and dairy produce generally.

The results of the soil analyses of this and previous years are now being collected and arranged in such a form that the characteristics of soils from different localities may be studied. Such a compilation should be of value in enabling us to form a correct judgment as to the nature and peculiarities of the soil from different parts of the colony.

In connection with the manure analyses, a pamphlet prepared in 1894 was revised and brought up to date in this year. This publication shows the composition and relative value of the various fertilizers offered for sale, affording farmers information as to the nature and value of any fertilizer they may desire to purchase. It also acts as a check upon the quality of the manures offered for sale.

Analyses were also made of many products manufactured for private persons for their own use, as well as of ashes and waste-products of all descriptions, with a view to determining their economic value. Assistance was also afforded to exporters of agricultural produce in guaranteeing the purity of the articles, particularly honey and bees' wax.

Analyses of sugar-beet, grown in different parts of the Colony, from seed supplied by the Department, were undertaken in order to judge of the fitness of different districts and of the different varieties for the production of sugar.

(*b*) Special work.—An investigation was undertaken into the milling qualities of a number of the different varieties of pure wheats. This is the first time such work has been done, and its main object is to ascertain what are the best varieties for the farmer to produce, taking into account their suitability to different districts, the milling quality of the grain and the bread-making quality of the flour. The characteristics of the different varieties are thus established, and the results indicate the manner in which by proper selection or cross-breeding, an improvement may be effected in the quality of the wheats grown in the Colony. The results of the first batch of these experiments were published in the *Agricultural Gazette* during 1895, and have been followed by a further batch during this year.

This work has suggested a number of problems which require solution, of which one is the subject of an investigation now almost complete and ready for publication. This refers to the power possessed by flours from different grain of absorbing water. This property, of great importance to the bread-maker, is found to be due to the varying proportion of the soluble and insoluble proteids contained in the gluten.

An investigation into the chemical nature of the wines produced in the Colony was commenced with the publication of the results of analysis of some wines, from the northern river vineyards. The results of a further batch of northern river wines will appear in the forthcoming number of the *Gazette*. In addition to the purely scientific interest attaching to this investigation, it affords a means of comparing our wines with those of other countries, and indicates in what direction improvements are possible.

Samples of the different timbers of the Colony are being examined with a view to determining the nature and quantity of their mineral constituents. Analyses of the ash of various timbers grown in different parts of the Colony, systematically carried out should give us valuable information, firstly as to the nature (chemical) of the soil on which they grow, and also of their value

as fertilizers. This work has been commenced and a preliminary batch of results will shortly be ready for publication.

Australian Museum.—During the past year little or no original research was conducted, but work was confined almost exclusively to a general renovation of existing collections, a weeding out of old specimens and duplicates, and their replacement by better, and previously unexhibited examples. By this means the whole of the Mammalia (skins) were reclassified, so far as the limited space available for this important class would allow, and it is much to be regretted that curtailment of an undoubtedly fine series was found necessary.

Amongst the Birds, the Australian Psittaci were rearranged, and the Nest-group collection freely added to.

Owing to the discovery of the "White-ant" early in the year in that portion of the roof surmounting the Fish and Reptile Gallery, necessitating the entire removal of the collections, little work was attempted in these classes, with the exception of the preparation of additional models of snakes.

In the Invertebrata, and Minerals, work was confined to amplifying the newly arranged specimens. The space assigned to the Invertebrata after the late extension of the building is now found to be quite inadequate, and as in the case of the Mammalia only trivial additions can in the future be made to this section.

In the Ethnological portion of the Museum good work was accomplished by the first attempt at a systematic arrangement of the Australian Stone-weapons and Implements, and general manufactures of the Aborigines, together with a very fine set of carved tree trunks. Cases of North and South American Prehistoric Pottery were also arranged. The Australasian Invertebrate Fossils were wholly reprepared and systematically arranged in the new cases prepared for their reception.

Board of Health—Laboratory.—This laboratory was definitely instituted by the Board in February, 1895. Its purpose is the investigation of disease in man, and of those diseases of the lower

animals which are liable to be transmitted to man, as well as experimental enquiries concerning all hygienic matters from a biological aspect. The need for biological investigation is imperative owing to the giant growth of bacteriology, and its ever increasing importance in public health. The control which the Board exercises over milk and meat supplies, diseased animals, noxious trades, etc., renders such investigations indispensable to the Department. The following brief notes indicate the nature of the principal investigations undertaken during 1895.

Tuberculosis—It is the custom of the veterinary staff to submit specimens for examination where suspicion of tuberculosis exists. Milk from diseased udders of cows, portions of carcases of animals, etc., in which the signs of disease are indefinite, are subjected to rigid microscopical scrutiny. The demonstration of *Bacillus tuberculosis* in such specimens is followed by seizure and destruction, and a source of infection for human beings is thus removed.

In connection with the work on tuberculosis, a series of examinations has been made of cattle which to all outward appearances, were in perfect health. When slaughtered the carcases presented every appearance of prime marketable beef. Signs of disease were only to be found in the internal organs, and in every case examined the disease proved to be tuberculosis. The results of the examinations show the insidious nature of the disease in animals. It may be present for years without presenting any external evidences of its existence. Experiments with tuberculin as a diagnostic agent for tuberculosis in cattle were attended with satisfactory results, and the conclusion was arrived at that this substance is capable of rendering valuable aid in the detection of the disease.

Anthrax.—The work on this subject has consisted of the examination of specimens forwarded by stock inspectors from various parts of the Colony in which this disease is prevalent amongst sheep. Where the first cases in a flock are not distinctive, the microscopic demonstration of the bacillus of anthrax renders important service in giving certainty of diagnosis and precision in efforts to check the disease.

Diphtheria; its diagnosis and treatment.—One of the features of the past year was the general introduction into this Colony of the use of antitoxic serum for the cure of diphtheria. This material, the first of its kind which has acquired a definite place amongst therapeutic measures, consists of the serum separated from the blood of horses which have undergone special preparatory treatment before being bled. The preliminary treatment is such that the serum obtained becomes powerfully curative of diphtheria. The Health Department instituted and maintained during four months, the importation and gratuitous distribution of supplies of this serum to qualified medical practitioners applying for it. After that time local druggists being prepared to supply the remedy its importation by the Department was stopped. The results of the use of the serum supplied by the Health Department were embodied in a report presented to Parliament in August 1895.[1]

The data contained in the report show that the results of the treatment with antitoxin serum are highly satisfactory, "since they appear to show that the mortality has been much reduced, that the cases have been rendered milder in their course, and that no untoward effects have been developed as a result of any undesired bye-action of the remedy. The estimated number of human lives saved in New South Wales would thus be about two hundred (200) per annum."

Subsequent reports appearing in the medical journals of this Colony more than confirmed this opinion of the Board, and the most satisfactory results have been reported from the Sydney and Brisbane Children's Hospitals. Indeed the testimony from all parts of the world is so unanimous as to silence all dissent, and we may congratulate ourselves on the possession of a remedy which robs diphtheria of the major part of its terrors. In connection with the distribution of the serum, the Health Department undertook to examine specimens from the throats of persons suspected of having diphtheria. This disease in its severer forms

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1 Report by Board of Health to Legislative Assembly N. S. Wales. —Antitoxin Serum for the Cure of Diphtheria, by authority, 1895.

is readily enough recognised by physicians, but there exist very numerous mild cases in which the symptoms do not appreciably differ from those of ordinary sore throats. These mild cases can spread the disease and lead to serious ones, and indeed it is by such unsuspected cases that the disease is disseminated. It is consequently of the utmost importance to recognise them and the department made provision for the above mentioned examinations which had for their object the detection of the specific form of the disease, *Bacillus diphtheriae.*

Leprosy.—A systematic enquiry into the histo-pathology of this disease has been initiated. During the past year four cases have been examined, and the extent of the disease in them ascertained. It is hoped that with the facilities we (unfortunately) possess for the study of this disease, we shall soon be in a position to make valuable contributions to the knowledge of this subject, and to add our mite to the ultimate object of such researches, viz., the cure of the disease.

The effects of the liver fluke.—This work consisted of an investigation as to the pathological effects produced in the liver of sheep by the presence of the parasite, *Fasciola (Distoma) hepatica.* As yet only one stage of the disease has been investigated.

During the year an epigootic disease amongst horses, characterised by loss of sight, has occurred in the Darling River districts. Examinations made in the laboratory showed chronic inflammatory changes in the optic nerves. Various plants have been suspected of causing this condition, and one of these—the Darling River melon *(Cucumis myriacarpus)*—has been examined. Experimental animals (rabbits and guinea pigs) refused to eat the melon. Forcible feeding with extracts did not produce any injurious effect. The experiments tend to show that the melon does not possess poisonous properties.

A disease met with in sheep, consisting of enlargement of lymphatic glands all over the body, giving rise to a condition resembling but distinct from tuberculosis, is the subject of an investigation at present in progress.

Another disease of unknown origin, consisting of ulceration of the cornea in cattle, which is believed to be epigootic, is also being investigated.

Hetinomycosis, pleuro-pneumonia, "cancers," and other diseases in animals, have also received some attention.

As instances of work of another character, I may mention the examination of filters and filtering materials as to their power of removing germs from drinking water, the testing of measures of disinfection, and a few other matters of general hygienic importance. These are, as yet, incomplete. It was also attempted to establish a systematic and regular examination of the Sydney water supply, but owing to the lack of accommodation and the numerous demands in other directions the examinations have perforce been irregular. As far as they go they indicate that the water is remarkably free from germs, and that those which occur are of a harmless nature, such as always exist in natural waters.

Botanic Gardens.—By the retirement of Mr. Charles Moore, F.L.S., the people of New South Wales lose the services of a veteran officer, who for no less than forty-eight years has acted in the capacity of Director of the Botanic Gardens. Mr. Moore was appointed in England in 1847 to the position of Botanist and Superintendent of the Botanical Gardens of New South Wales. He was recommended for this position by Professor Henslow, of Cambridge University, and by Lindley. On his arrival in New South Wales, his official title was changed to that of Director. Mr. Moore found at this time that there were only a few trees planted in the upper and lower gardens, and that the gardens were stuffed with duplicate plants, and that none of the plants were labelled. During his directorship Mr. Moore superintended the work of reclaiming the lower portion of the gardens between Cunningham's monument and the present wall around Farm Cove. and by dint of constant labour brought the gardens up to their present beautiful condition, which has made them famous throughout the world. Not only the Botanic Gardens, but the

University Park, Wentworth Park, Victoria Park, and Centennial Park, were laid out by Mr. Moore. Through Mr. Moore a lecture hall was erected in the Botanic Gardens, and for many years he delivered series of popular lectures, which were well attended, the lectures being discontinued only when the subject of botany came to be taught at the University of Sydney. In 1850 Mr. Moore made a voyage for botanic research purposes to the New Hebrides, Queen Charlotte Group, the Solomon Islands, and New Caledonia. In 1867 he went to the Paris Exhibition in the capacity of New South Wales Commissioner, and in 1874 he was delegate for New South Wales at the Universal Botanical Conference at Florence.

Mr. Moore's chief published works are "Woods of New South Wales," "Census of the Plants of New South Wales," and in collaboration with Mr. Betche "Flora of New South Wales." His good nature and courtesy are as well known to the public as to his colleagues on the Council of this Society and on the Board of Trustees of the Australian Museum. While Mr. Moore has merited the gratitude of the people of New South Wales for having added so much elegance and beauty to their capital city, he deserves the special thanks of this Society for his long and useful services on our Council. You will all, I know, unite with me in wishing Mr. Moore health and happiness in the future during his well earned rest from his official labours.

And here I am reminded that among those who formerly attended Mr. Moore's lectures was our new President, and this is a fitting occasion, I venture to think, for us to wish Mr. Maiden every success in the administration of the important office to which he has been appointed, and for which his past training and experience should so eminently fit him.

Geological Survey of New South Wales.—The most important work, economically at all events, accomplished lately by the Geological Survey has been the determination by Mr. Pittman of a great development of strata of Triassic Age holding artesian water in New South Wales. The probability that some of the

water in the artesian beds was derived not from Cretaceous, but from Triassic rocks was definitely suggested, chiefly on lithological grounds, by the Rev. J. M. Curran.[1] Mr. R. L. Jack, the Government Geologist of Queensland, in his able paper to the Australasian Association for the Advancement of Science at its Brisbane meeting, threw further light on this subject, and the Triassic Age of the strata penetrated in the Coonamble and Moree artesian bores was last year definitely proved by Mr. Pittman. The results of his important observations Mr. Pittman has already communicated to this Society, and he gives me to understand, that not only are the Coonamble and Moree bores drawing their supplies of water from the Triassic beds, but in all probability the Walgett bore also, in which the magnificent supply of from five to six million gallons of water per twenty-four hours has recently been struck. Mr. J. E. Carne, F.G.S., has likewise furnished important reports upon the lately discovered chromite deposits of the Gundagai-Tumut district, the newly discovered mercury deposits on Yuilgilbar Station, Clarence River, and on the auriferous beach sands containing platinum and iridium of the Richmond-Clarence district.

Amongst the reports contributed by Mr. G. A. Stonier, F.G.S., those relating to the fossiliferous rocks near Crow Mountain and Somerton appear particularly interesting, as the fossils as determined by Mr. R. Etheridge and Mr. W. S. Dun, confirm the previous opinion as to the extensive development in those areas of the Gympie beds. I should like to express my regret that my old colleague on the Geological Survey, last year resigned his position as Geological Surveyor, with a view of further prosecuting his geological studies in Europe.

Mr. J. B. Jaquet's report on the "Platinum Deposits of Fifield" show the growing importancè of that branch of the mining industry. About 1,200 ozs. of crude platinum are estimated to have been raised previous to the commencement of this year.

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[1] *Daily Telegraph*, January 20, 1894.

The subjoined analysis by Mr. J. C. H. Mingaye, F.C.S., proves this platinum to be purer than any hitherto discovered in New South Wales :—

Platinum	75·90	per cent.
Iridium	1·30	,,
Rhodium	1·30	,,
Palladium	traces	
Osmiridium	9·30	,,
Iron	10·15	,,
Copper	·41	,,
Gold	nil	
Lead	traces	
Siliceous matter	1·12	,,
	99·48	

Mr. W. S. Dun, the Librarian and Assistant Palæontologist has seen through the press amongst other important publications, Memoirs, Palæontology, Part 3, "Contributions to a Catalogue of Works, Reports, and Papers on the Anthropology, Ethnology, and Geological History of the Australian and Tasmanian Aborigines, Part 3, by R. Etheridge, Junr.; and Memoirs Palæontology No. IX." "The Fossil Fishes of the Talbragar Beds (Jurassic?)" by A. Smith Woodward, F.L.S., of the British Museum.

Mr. G. W. Card, Assoc. R.S.M., F.G.S.. has contributed some interesting articles to the Records of the Geological Survey on rich antimonial silver ores near Armidale, and certain interesting igneous rocks such as norites and peridotites.

Harbours and Rivers.—Nine harbours are in course of construction by the Harbours and Rivers Department at the present time :—Tweed, Richmond, Clarence River, Nambucca, Macleay, Trial Bay, Manning, and Newcastle. On those which are well advanced very favourable results are being obtained, and this justifies the Department in anticipating the success of those schemes which have more recently been undertaken.

During the year very large additions have been made to the wharfage and storage accommodation at Circular Quay, and other parts of Sydney Harbour. On the Richmond a scheme for reducing the damage done by floods is now in course of construction, and extensive embankments for the protection of the town of Grafton were also completed.

A dredging plant of forty dredges and twenty-nine steamers has been continuously at work during the year, and over six million tons of material have been lifted.

Several water supply schemes for country towns are in hand or have been completed, one of the most important being at Junee, where a concrete dam over forty feet in height has been erected.

One of the principal works to engage the attention of this branch was the construction of the Naval Depôt at Garden Island. A considerable portion of the island has been levelled down and the material used for its extension to give room for the necessary buildings. The barracks is a building of three floors, capable of accommodating officers and men, and is fitted on the most approved plan, the sanitary arrangements having received special attention. The workshops, two hundred and forty-eight feet by one hundred and thirty-two feet, include a machine shop, boiler shop, foundry for iron and brass, forge shop, tool and pattern shops, dynamo room, zincing room, engine room, boiler house, offices, etc., and have been fitted with machines capable of undertaking any naval work demanded of them. The naval and victualling store is a building two hundred and twelve feet by one hundred and twenty-eight feet. It has four floors, having a superficial area of ninety-four thousand feet, and is provided with five hoists and two lifts, with the necessary hydraulic plant. The coal store is capable of holding two thousand five hundred tons, and extensive coaling wharves have been provided to which all the stores are connected by lines of tramway. In addition to the main buildings, there are stores for inflammable materials, a saw mill, gun mounting shed, dining room for workmen, chain

and anchor store, paint and oil store, timber storing shed, a receiving shed, two boatmen's shelters on the wharf, extensive offices, bath and dressing rooms, and five brick cottages for the accommodation of warrant officers and storemen. Six hundred and fifty feet of wharfage has also been provided, capable of berthing vessels drawing twenty-eight feet. The shear-legs for removing heavy machinery, guns, and plant, lift a working load of one hundred and sixty-tons, and have stood a successful test of two hundred tons. A six-inch water-main connects the Island with the Sydney water supply, and the offices are in telephonic communication with the city. A contract is now in hand for a complete electric lighting installation, and this with the addition of a boat repairing shop, will complete the works at present contemplated.

Works carried out by the Bridges Branch in 1895.—During 1895 the Bridges Branch submitted for tenders one hundred and sixty-four works at an estimated cost of £95,000 and of a total length of two and a-half miles. Included in these is a steel lift-bridge over the Murray River at Swan Hill, consisting of two timber truss side spans with a lifting span formed of steel girders carrying a timber deck, giving a clear opening between cylinders of forty-eight feet. The lift can be raised thirty feet clear of the highest flood by means of gearing placed on top of four wrought iron towers, one at each corner of the span, thus giving ample headway for river traffic at all stages of the river.

At Wallis Creek, Maitland, a new bridge is in course of construction, designed to replace the old timber truss bridge, which after a life of forty-three years (during which the superstructure has been twice renewed) is now in an advanced state of decay. The new structure will consist of three spans formed of steel rolled girders, on rolled girder piers with concrete bases founded on piles, giving a deck thirty-five feet wide formed of tarred metal on buckled plates.

The Kangaroo River Suspension Bridge, on the Moss Vale to Nowra Road, will when completed form a handsome example of

its type, on each side of the deep gorge through which the river flows at this point two masonry towers in the Tudor style, connected by a Tudor arch, will carry the cables of a suspension bridge of two hundred and fifty-two feet span, stiffened with a timber truss hinged at the centre and ends, this work is now in progress.

The economy of the use of timber in place of iron or steel for bridge trusses in this Colony finds an example in the new bridges recently erected over the Murrumbidgee River at Wagga Wagga, and over the Edwards River at Deniliquin. The former has been erected alongside of the old Company's bridge at Wagga Wagga, and reckoned by floor space per span, is by far the largest timber structure yet erected in the Colony. It consists of three one hundred and ten feet trusses on cylinder piers, with timber approach spans, the total length being six hundred and forty-five feet, and the carriage way twenty-four feet four inches, with one four feet six inches footway. The trusses and deck are of a novel design, and consist of timber for chords and braces throughout, with wrought iron suspension rods, the total quantity of timber used being about 25,000 cubic feet, obtained principally from Wyong and the North Coast. The completed cost of the work was £14,200. Deniliquin Bridge may be taken as a type of the many truss bridges which are erected every year by the department. It is formed of three ninety feet timber truss spans of the new standard type, on timber piers with timber approach spans, the width of roadway being twenty feet.

Contracts have been let during the past twelve months for timber truss bridges over Namoi River at Walgett, Double Creek, at Brogo, Little Plains River near Bombala, Myrtle Creek near Casino, Cooradigbee River and Cudgegong Creek in addition to many beam bridges, both of high and low level types, in different parts of the Colony.

Sydney Observatory—Star Photography.—During the year an unusual amount of dust-haze has interfered with the photographic work to some extent, but five hundred and fifteen star photo-

graphs have been obtained; heretofore nearly all the photographs were taken with exposures of one or two minutes, but now that the plates are being worked at to make a chart of the heavens, the exposures have been from thirty to sixty minutes, and hence the number obtained is not so great as it has been. Thirty-nine plates were devoted to special work on star clusters and nebulæ.

Meridian Work.—At the suggestion of Sir Charles Todd, Adelaide, Melbourne, and Sydney have made special observations for a new determination of Australian latitudes. One thousand and fifty observed transits have been taken, and seven hundred and sixty-four determinations of declination.

Magnetic Observations.—During the past year two French officers of the "Missions Magnétiques du Bureau des Longitudes Ocean Pacifique Ouest," came to the Observatory and made magnetic observations. It is remarkable how little variation there has been in the declination during the last thirty-seven years. In the early days of the Colony the lowest variation of the magnet was in 1818, viz., 8° 42′ 0″; it then increased rapidly and during 1857-8 was 10°; then it fell steadily until in 1873 it was 9° 32′ 30″; from that time to 1882 it varied from 9° 32′ 0″ to 9° 35′ 47″; then fell to its minimum in 1893, 9° 28′ 37″; and then increased again until now, 1896, it is 9° 38′ 0″

Meteorology.—During the year the rainfall report of 1894 was published. In addition to the usual data about rain, rivers, and evaporation, it contains a map shewing for each square degree the percentage of rain above or below the average, another shewing temperature of every month of the year for each square degree, and a third map giving the mean, the highest, and the lowest recorded temperatures, and the average shade in each square degree.

A special study of meteorological records has been made with a view to discovering any period or cycle in the weather, and the effort has been successful, and the result cannot fail to be of great use in pastoral and farming industries.

A study has also been made of icebergs in the Southern Ocean, which shews a very unusual number of them in the tracks of vessels to and from Australia. The result has been published as a pamphlet.

Railway Construction Branch—Railway Survey Work.—A branch, leaving the Molong-Parkes railway at Parkes, has been permanently staked as far as Condobolin, a distance of sixty-three miles, and a survey for extension of this line viâ Menindie to Broken Hill has been undertaken and is in progress. Between Moree and Inverell, a distance of one hundred and one miles, trial surveys have been made with a view to connect Inverell with the main railway system by the railway now under construction from Narrabri to Moree. The survey of a branch line from Tamworth to Manilla, leaving the main line at Tamworth has been completed. This branch is twenty-eight miles in length. A survey is in progress for a railway from Singleton to Jerry's Plains, a distance of twenty-eight miles.

For improving the grades and cutting out the Great Zig-zag on the Great Western Railway, a large amount of survey work has been carried out, comprising surveys of over forty miles of railway, also other improvements on the Western line and between Picton and Mittagong on the Southern, in order to reduce the heavy grades, a deviation extending over thirty-five miles has been surveyed. The connexion of Broken Hill with the railway system of the Colony viâ Condobolin and Menindie is under consideration of the Government, and a survey over the proposed route is in progress.

The following proposed lines have been recently inquired into by the Parliamentary Standing Committee on Public works: Tamworth to Manilla, twenty-eight miles long; Nevertire to Warren, twelve and a half miles long.

Railway construction in progress—Narrabri to Moree, sixty-three miles nine chains in length, estimated cost £153,000; Parkes to Bogan Gate, twenty-three miles, thirty-eight chains in length,

estimated cost £127,000 ; Jerilderie to Berrigan, twenty-one miles sixty-six chains in length, estimated cost £42,475. Tenders are about to be invited for a new line from Bogan Gate to Condobolin, forty miles in length.

Tramway Work.—A proposal has been worked out involving detail surveys and estimates for an electric tramway from Circular Quay to Redfern Railway Station and Harris-street, Ultimo, a length of about three and a half miles of double line. This has been recently under the consideration of the Public Works Committee. Also for an electric tramway to Mossman's Bay, one and a half miles, being an extension of the existing electric tramway along the Military Road. Also for a steam tramway to the Kensington Park and the Rifle Range, a distance of about three miles.

Trial surveys and estimates have been made for extension of the Ocean-street tramway to Rose Bay, a distance of one and a half miles, by electric tram. A report has been submitted by Mr. Deane, the Engineer-in-Chief for Railway Construction, dated September 9, 1895, on his proposed development of the tramway system in Sydney and suburbs, including recommendations for substituting electricity as the motive power on portions of the existing lines. This report was based on results of observations made by Mr. Deane during his late visit to Europe and America.

Technological Museum.—Mr. Maiden and Mr. Baker during the past twelve months have described and figured many new phanerogamic species. Microfungi have also received some attention, and a number of new species have been added to science. Mr. Maiden has requested me to call particular attention to the microfungi of this Colony. He states that our floral collections in this particular branch of plants are poorer than those of any other colony, though the flora of New New South Wales will probably prove to be the richest in microfungi. Botanical identification of native timber trees has claimed considerable attention, and is expected to yield important commercial results. Timber merchants naturally hesitate to invest money in timbers unless

they can be assured of continuous supplies of the *same kind*, a matter which must be settled primarily on botanical evidence.

The experimental plant for the distillation of Eucalyptus oil is now in full working order. In the Chemical Laboratory Mr. Maiden and Mr. Smith have been working at a further classification of the *Eucalyptus* exudations known as kinos. The discovery of two new organic substances in those kinos belonging to the turbid group, viz., Eudesmin ($C_{26}H_{30}O_8$) and Aromadendrin, has advanced our knowledge considerably, and has opened out a way for their scientific classification and accurate arrangement. Whether these new bodies are of therapeutic value has not yet been investigated. The discovery of Aluminium Succinate as an exudation of *Grevillea robusta*, R. Br., is of some importance, as both the acid and the base are of rare occurrence under these conditions, and a natural salt of this character has not previously been discovered. Part I. of original investigations on the un-described gums, resins, gum-resins and kinos of Australia was also submitted to this Society during the year, and is published in its proceedings, as is also the other chemical research work mentioned above.

Mr. W. W. Froggatt, has arranged and set out a collection of white-ants *(Termites)*, together with timbers attacked by them, and enlarged drawings showing the different forms of the workers, soldiers, queen and winged males and females. Several new type specimens have been added to the Australian collection, which now fills five wall cases.

University Laboratories—Anatomy.—Professor Wilson and Mr. J. P. Hill have for the past eighteen months been engaged upon a research into the development of the teeth in marsupials, particularly in the genus *Perameles*. The results are nearly ready for publication. They believe that their conclusions will be found to be of interest and importance, more especially in regard to the problem of tooth succession, and diphyodontism not only in marsupials but in mammalia generally. Their conclusions differ materially from those usually entertained at the present time.

Biological Laboratory.—I now come to the subject of a very important discovery. Speaking of this discovery, a leading scientific man in London this year classed it with Röntgen's discovery of the X rays, as amongst the most sensational that had been made during the past twelve months, and one that would lead to serious modifications of the views generally held about the marsupialia. He was alluding to the discovery of a placenta in the bandicoot by Mr. J. P. Hill, the Demonstrator at the University Biological Laboratory. This is perhaps one of the most important, if not the most important, scientific discovery as yet made in Australia.

Mr. J. P. Hill has for some time past been engaged in studying the development of marsupials, especially with regard to the relations of the fœtal membranes. The most important result yielded by this investigation is the discovery of a true allantoic placental connection in the bandicoot, *Perameles obesula*. A short preliminary account of this connection was read before the Linnean Society in November of last year. It was there shown that not only does the vascular allantoic fuse with the serous membrane, but that the latter in the region of the fusion disappears as a distinct layer, and the allantoic capillaries become closely applied to the surface of the uterine mucosa, and indeed dip into the latter as irregular and short vascular processes. These processes come into very close relation with the maternal capillaries of the uterus, and in this way transfusion can readily take place between the two blood streams. A distinct connection is thus established between fœtal and maternal tissues—a connection which not only allows the direct transmission of part of the nutrient material necessary for the growth of the embryo, but which also serves as a respiratory organ. Up to the discovery of this placental connection in the bandicoot, the absence of any such connection was universally regarded as one of the best established and most characteristic features in the marsupial organisation. In the majority of marsupials indeed, no such placental connection is ever developed, but in view of the condition in the bandicoot we

can no longer include the marsupialia as a whole under the name aplacentalia.

Any person residing in the country desirous of helping Mr. Hill in his interesting and important investigations, would render material assistance by placing themselves in communication with him at the Biological Laboratory of the University of Sydney, with a view to arranging for securing specimens of opossums, native cats, bandicoots, or any other kind of marsupial. This important discovery by Mr. Hill was not the result of chance, but the outcome of patient and systematic research, a fact which still further enhances its merit, and this Socicty will not hesitate, I am confident, to offer their warm congratulations to Mr. Hill.

Professor Haswell has during the past year been engaged more or less continuously in completing and seeing through the press the fine and well illustrated textbook on biology, which he has written in collaboration with Professor Parker of Dunedin. This important work is expected to be published in the next few months. He has also contributed a few notes on the structure of the nautilus.

Chemical Laboratory.—Professor Liversidge's recent researches such as those on the occurrence of gold in sea-water, the crystallization of gold etc., have already been published in our Proceedings. His demonstrator Mr. J. A. Schofield has collaborated with Mr. Smeeth and myself in our paper on the Antarctic rocks collected by Mr. C. E. Borchgrevink.

Engineering Laboratory.—Owing to the absence of Professor Warren in Europe and America during a great portion of last year, little original work has been done, with the exception of testing concrete. The munificent bequest of Mr. P. N. Russell of £50,000 to the Engineering Department, promises a considerable expansion of this School, and a widening of its field of usefulness in the near future.

Geological Laboratory.—Besides the paper above referred to, an important contribution to our knowledge of perlitic structure

in lavas has been made by Mr. W. F. Smeeth, Lecturer in Metallurgy and Demonstrator in Geology. This paper has been favourably criticised in *Nature*, and in the *Geological Magazine*. A discovery likely to prove of importance has been made by my third year students and myself, of radiolarian jaspers in the Barraba and Bingara Districts of this Colony. Reference will be made to this later.[1]

Physics Laboratory.—Professor Threlfall has kindly furnished me with the following report as to recent research work in his laboratory :—" My time during the year 1895-6 has been occupied (1) In purifying selenium. In this I have succeeded as well, but I do not think better than Nilson and Petterson, who determined its atomic weight. The electrical properties of the purified substance are now being examined. (2) Messrs. Farr and Allen spent a considerable time in endeavouring to complete a series of observations on the magnetic permeability of bismuth. The immediate object of the experiment was not attained, owing to a difficulty arising from a hitherto unsuspected cause. This matter still awaits investigation. (3) A fairly complete study of dielectric waste of energy in rotating fields has been carried out and is nearly ready for publication. (4) Considerable improvements have been made by Mr. Pollock in the gravity meter, and it is hoped that the present form of instrument will be of sufficient accuracy to be of some use."

Physiological Laboratory.—Dr. C. J. Martin, has lately been engaged chiefly in studying the following :—Physiological action of snake-poisons ; further observations on the venom of platypus; development of platypus ; experiments in the pharmacology of arsenic and strychnine (for the Dean Commission). You are all aware that Dr. Martin's essay on snake-poison was awarded the prize and medal by this Society, and it is satisfactory to note that his recent physiological researches have been very favourably

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[1] Since the above was written abundant radiolaria in black chert of probably Upper Silurian Age, have been discovered by me in the neighbourhood of the Jenolan Caves, New South Wales.

reviewed by one of the leading scientific journals of Europe, *Science Progress*. The idea of binding together with a view to distribution among scientific societies etc., the various papers representing the annual research work done at the University Laboratories, originated with Dr. Martin, and he is to be congratulated on having this year succeeded in carrying out this idea. The volume in question is before you to-night.

Scientific Work outside New South Wales.—Professor Alexander Agassiz has lately been engaged in examining the Great Barrier Reef of Australia, and taking soundings across it. We may shortly look forward to a scientific report by one who has made a specialty of coral reefs, and who is acknowledged to be one of the greatest living authorities upon that subject.

Expedition to bore the Coral Atoll of Funafuti in the Ellice Group.—Five years ago, Professor Anderson Stuart was consulted by a committee of the Royal Society as to the possibility of Sydney being the starting point for an expedition to bore one of the coral atolls of the Pacific. Professor Stuart consented to taking the administrative work in New South Wales, and he is to be congratulated upon the expedition having now become an accomplished fact, as the warship H.M.S. "Penguin," conveying the members of the expedition and the diamond drill plant sailed from Sydney on May 1st ult. The expedition is in charge of Professor Sollas, F.R.S., and Mr. Gardner as zoologist, represents the Balfour Research Fund of Cambridge, while Mr. Charles Hedley of the Australian Museum, goes as the representative of this Colony. The Government of New South Wales have contributed largely to the expedition by lending a complete diamond drill plant, making no charge for the use of the plant, but stipulating that the committee of the Royal Society of London shall make good any loss or damage to the plant. The results of this expedition will be awaited with the greatest interest all over the scientific world. It is hoped that by means of this expedition Darwin's earnest wish as expressed in the following letter to Agassiz will at last be realised :—"I wish that some doubly rich

millionaire would take it into his head to have borings made in some of the Pacific and Indian atolls, and bring home cores for slicing from a depth of five hundred to six hundred feet."

III.—Summary of our present knowledge of the Structure and origin of the Blue Mountains of New South Wales.

In the following remarks only the most salient features are touched upon.

References by previous observers.—The most important of these is probably that of Charles Darwin.[1] My excuse for introducing a lengthy quotation from Darwin's work is that the passage is extremely suggestive on many points of importance in the structure of the Blue Mountains, which I propose to criticise. After describing the great platform of sandstone which rising westwards attains an elevation in places of over 4,000 feet, at a distance from Sydney and the coast of about one hundred miles, he states that the sandstone is at least 1,200 feet thick, "and in some parts is apparently of greater thickness; it consists of small grains of quartz, cemented by white earthy matter, and it abounds with ferruginous veins."[1] * * * "The sandstone contains pebbles of quartz; and these generally increase in number and size (seldom, however, exceeding an inch or two in diameter) in the upper beds: I observed a similar circumstance in the grand sandstone formation at the Cape of Good Hope. On the South American coast, where Tertiary and Supra-tertiary beds have been extensively elevated, I repeatedly noticed that, as the sea became shallower, the force of the waves or currents increased."[2] * * * "I was surprised at observing that in some specimens (of sandstone.—T.W.E.D.) nearly all the grains of quartz were so perfectly crystallised with brilliant facets that they evidently had not in their *present* form been aggregated in any previously existing rock." * * * "The strata of the Blue Mountains appear

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[1] Geological Observations on the Volcanic Islands and parts of South America visited during the voyage of H.M.S. 'Beagle.' Second edition, pp. 146–154. [2] *Op. cit.*, 147.

to the eye horizontal; but they probably have a similar inclination with the surface of the platform, which slopes from the west towards the escarpment over the Nepean, at an angle of one degree or of one hundred feet in a mile. The strata of the escarpment dip almost conformably with its steeply inclined face, and with so much regularity that they appear as if thrown into their present position; but on a more careful examination they are seen to thicken and to thin out, and in the upper part to be succeeded and almost capped by horizontal beds. These appearances render it probable, that we here see an original escarpment, not formed by the sea having eaten back into the strata, but by the strata having originally extended only thus far. Those who have been in the habit of examining accurate charts of sea coasts, where sediment is accumulating, will be aware that the surfaces of the banks thus formed, generally slope from the coast very gently towards a certain line in the offing, beyond which the depth in most cases suddenly becomes great. I may instance the geat banks of sediment within the West Indian Archipelago, which terminate in submarine slopes, inclined at angles of between thirty and forty degrees: every one knows how steep such a slope would appear on the land. Banks of this nature, if uplifted, would probably have nearly the same external form as the platform of the Blue Mountains, where it abruptly terminates over the Nepean."[1]

It is evident from the above passage, that Darwin regarded the eastern escarpment of the Blue Mountains as an *original* structure in the Blue Mountains, formed, that is, contemporaneously with the deposition of the sandstone.

Darwin states further,[2] "The strata of sandstone in the low coast country, and likewise on the Blue Mountains, are often divided by cross or current laminæ, which dip in different directions, and frequently at an angle of forty-five degrees." Speaking of the grand valleys of the Blue Mountains, from 1,500 to 2,000

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[2] *Op. cit.*, pp. 149–150. [3] *Op. cit.*, p. 150.

feet deep, which terminate at their upper ends in vast amphitheatrical depressions bounded by gigantic walls of sandstone, Darwin says,[1] "To attribute these hollows to alluvial action, would be preposterous. * * * Some of the inhabitants remarked to me, that they never viewed one of these bay-like recesses, with the headlands receding on both hands, without being struck with their resemblance to a bold sea coast. This is certainly the case. * * * But then immediately occurs the startling difficulty, why has the sea worn out these great, though circumscribed, depressions on a wide platform, and left mere gorges, through which the whole vast amount of triturated matter must have been carried away? The only light I can throw on this enigma, is by showing that banks appear to be forming in some seas of the most irregular forms, and that the sides of such banks are so steep (as before stated) that a comparatively small amount of subsequent erosion would form them into cliffs; that the waves have power to form high and precipitous cliffs, even in land-locked harbours, I have observed in many parts of South America. * * To apply these ideas to the sandstone platforms of New South Wales, I imagine that the strata might have been heaped on an irregular bottom by the action of strong currents, and of the undulations of an open sea: and that the valley like spaces thus left unfilled, might during a slow elevation of the land, have had their steeply sloping flanks worn into cliffs; the worn down sandstone being removed, either at the time when the narrow gorges were cut by the retreating sea, or subsequently by alluvial action."[2]

It is equally clear from the passages above quoted, that Darwin regarded the valleys of the Blue Mountains like the eastern escarpment, as original depressed areas in the region of sedimentation at the time when the sandstones of the Blue Mountains were being deposited. Later observers favoured, by far better sections than those to which Darwin had access, have collected evidence which proves that Darwin's views, for reasons which will be adduced presently, must now be considerably modified.

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[1] *Op. cit.*, p. 153. [2] *Op. cit.*, p. 154.

The Rev. W. B. Clarke, F.R.S., ascribes a thickness of from eight hundred to one thousand feet to the Hawkesbury Sandstone, and states that on the summit of the Blue Mountains, and along the Grose River, the thickness of the series is very much greater than near the sea.[1]

The following statements by Mr. C. S. Wilkinson, the late Government Geologist of New South Wales,[2] bear directly upon the subject under discussion :—"It would appear that the coal measures had been upheaved and partly denuded, and that in the shallow freshwater lakes which filled the depressions, the shale beds were deposited. Then succeeded a subsidence of the land to sea-level, and the area in which the Hawkesbury Sandstones were laid down became a tidal estuary, mostly of freshwater.

The current bedding dips in various directions, but it is chiefly to the north-north-east, as though the prevailing currents came from the south-south-west. After the Hawkesbury deposits had attained a thickness of about 1,000 feet, they were upheaved and a freshwater lake was formed, in which accumulated the muddy sediment of the Wianamatta series. Thus, from the Middle Coal Measures to the Wianamatta series inclusive, the strata amounting to about 5,000 feet in thickness, are of freshwater or estuarine origin; and with the exception of the upheavals or oscillations of level referred to, this part of Australia must have presented land features from the Carboniferous period of the Palæozoic era to the Wianamatta of the Mesozoic.

Mr. C. S. Wilkinson, also states in another place,[3] "The vastness of the depth and extent of the precipitous gorges and valleys of the Blue Mountains inspire one with feelings of silent awe and wonder, and impress the minds of some persons with the notion we hear so frequently expressed, that such enormous ravines in

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1 Remarks on the Sedimentary Formations of New South Wales, by the Rev. W. B. Clarke. Fourth Edition, Sydney, 1878, pp 70 - 71.

2 Mineral Products etc. of New South Wales, Sydney 1887, p. 75.

3 The Railway Guide of New South Wales, Third Edition, p. 127. By Authority, Sydney, 1886.

the mountains must have required violent convulsions in the earth's crust for their formation. But if we examine the rocks on all sides of the valley, we see no breaks nor signs of violent disturbance as suggested. The various beds of rock in horizontal strata may be seen to continue uninterruptedly around the sides of the valley, and the succeeding layers of rock, as we descend one side of the ravine, gradually approach the corresponding layers on the other side, until at the bottom, in the bed of the water-course, we find that they actually join, which they would not do if the sides of the ravine had been violently torn asunder. We perceive, therefore, that the various outcropping strata must once have been continuous right across the valley or ravine, and that they have been removed by some agency without disturbance of the underlying beds. What then is this agency? Not *volcanic fire* but *running water*." The above passage makes it clear that Mr. Wilkinson was of opinion that the valleys of the Blue Mountains were due to subaerial erosion only, and that they were not, as Darwin thought, original depressions, deeply indenting submarine banks, the sides of which had subsequently been rendered precipitous, partly by marine, partly by fluviatile erosion.

One of the most important statements about the geology of the Blue Mountains is the following by the same observer[1]:—"It will thus be seen that this locality (Port Hacking), is over a very deep portion of the coal basin. The eastern portion of this basin has been apparently faulted and thrown down beneath the waters of the Pacific Ocean, the precipitous coast, and a line about twenty miles east from it, marking approximately the lines of dislocation. The deep soundings immediately beyond this would seem to favour this view, so that here the bed of the ocean probably consists of the old land surface which once formed a continuation of that upon which the city of Sydney now stands, and which has been faulted to a depth of over 12,000 feet; the length of the faulted area is not yet known, but it probably does not extend along the coast beyond, if so far as, the north and south limits of the Colony.

[1] Mineral Products &c. of New South Wales. By Authority, Sydney, 1882, p. 52. (In Second Edition 1886, p. 70.)

"The abrupt eastern margin of the Blue Mountains, up which the Great Western Railway Zig-zag ascends at Lapstone Hill, near Emu Plains, marks the line of a similar though not such an extensive fault, by which all the country between it and the coast was thrown down to its present level—the depression being so great that the ocean water flowed into the old river valleys, one of which forms the beautiful harbour of Port Jackson. * * * We have evidence that these faultings probably took place towards the close of the Tertiary epoch; for no marine Tertiary deposits are known along this portion of the coast of Australia, whereas in New Guinea on the north, and in Victoria on the south, the marine Miocene beds occur at elevations up to eight hundred feet above the sea. Had this low-lying country along the east coast of Australia then existed, it must have been covered by the Miocene sea, and doubtless some traces of the marine strata of that period would have escaped denudation and remained as those have which are seen in Victoria and elsewhere; but it is very probable that until or during the Pliocene period it stood at a much higher level, and extended some distance beyond the present coast line. Then, again, the Tertiary deposits throughout East Australia show that the valleys draining the Great Dividing Range have been chiefly eroded since the Miocene period, for we find deep valleys and ravines cutting through later Tertiary formations; therefore the sinking of the land traversed by any of these valleys such as that of Port Jackson, evidently took place in comparatively recent geological times, and may have been contemporaneous with the extensive volcanic eruptions of the Upper Pliocene Period, during which the southern portion of Victoria especially was the *locale* of great volcanic activity. How far this old land extended to the east it is difficult to indicate; but no doubt future observations upon the distribution of the marine and terrestrial fauna and flora of the South Pacific region will throw much more light upon the subject."

In 1882, the Rev. J. E. Tenison-Woods contributed an important paper on the Hawkesbury Sandstone,[1] reference to which and

[1] Journ. Roy. Soc. N. S. Wales, Vol. xvi., 1882, pp. 53 – 116.

to the interesting discussion which followed is given below. He contended that the Hawkesbury Sandstone was of Æolian origin, and analogous to the recent and Pliocene blown sands of Double Island Point, one hundred miles north of Cape Moreton, and the Pliocene sands of the southern coast of Victoria and South Australia. In the Queensland example the Æolian sand rock is up to two hundred feet thick, and the angle of dip of the current-bedding is stated to be frequently as high as 30°.

Mr. C. S. Wilkinson, however, in discussing this paper, stated that the highest angle of dip he had ever observed in the current-bedding of the Hawkesbury Sandstone was 26½°, and that the prevailing angle of dip was only 20°. This, he considered, was a strong argument against the Æolian origin of the Hawkesbury Sandstone. Mr. Wilkinson also pointed out[2] that some of the pebbles in the Hawkesbury Sandstone were as much as six inches in diameter, and "may have been derived from the Hartley Ranges."

The Rev. J. E. Tenison-Woods considered that the rounded character of the sand grains was characteristic of air-worn rather than of water-worn sands, and he compared them with the "millet seed" sand grains of the Triassic Rocks of Europe. He accounts as follows for the sparkling of the sandstone when viewed in sunlight[3]:—"When seen under polarised light some of the larger fragments (of quartz in the Hawkesbury Sandstone.—T.W.E.D.) would manifest their compound character, and by watching the effect of the light as the nicol prisms were revolved, the forms of the rounded grains embedded in transparent silica could be made out." He subsequently gave up the theory as to the Æolian origin of the Hawkesbury Sandstone in favour of a tuffaceous origin. The latter theory is, I think, in part correct as applicable to some of the Narrabeen beds in the Hawkesbury Series.

A short popular description of the Blue Mountains has been written by Dr. J. E. Taylor. Although many of the statements are open to question, the following passage may be quoted as

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1 *Op. cit.*, p. 94. 2 *Op. cit.*, p. 95. 3 *Op. cit.*, p. 65.

being fairly accurate.[1] "But even supposing the Hawkesbury Sandstones were formed under terrestrial conditions, there must have been a subsequent depression. The sea came over their site, and covered them with the fine argillaceous sediment of the Wianamatta shales, as their enclosed fossil fishes indicate.[2] Then followed a slow and extensive upheaval during which the soft shales must have been greatly denuded. Afterwards succeeded the era when the great Nepean Fault commenced, and the country south (east—T.W.E.D.) began to sink, whilst perhaps that to the north (west—-T.W.E.D.) was upheaved to form the region of the Blue Mountains. At length, with the exception of comparatively small patches, the Wianamatta shales were completely peeled off the Blue Mountains. The action of rain, running waters, frosts, snows, wind, and sun * * * began to eat into the harder Hawkesbury Sandstone rock beneath. It was merely a question of time. The work is still going on, and the total results are visible in the grand and awe-inspiring views presented at the Weatherboard (Wentworth Falls—T.W.E.D.), in the Grose Valley and elsewhere. There we behold immense valleys scooped out to more than 2,000 feet, walled in by mural precipices with 800 or 900 feet of sheer perpindicularity, over which streams of water fling themselves. to be lost in gauzy mist before reaching the bottom. * * * From our giddy point of vantage, the arboreal vegetation below looks like velvet pile. * * * The rich yellow walls of sandstone precipices on which the sun is shining, gleam with almost dazzling brightness, whilst the corresponding walls of the other side of the valley are plunged in densest gloom. Out of, and beyond the curving and widening valley we are gazing down

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[1] Our Island-Continent—A Naturalist's Holiday in Australia. By Dr. J. E. Taylor, F.L.S., F.G.S., London, 1886, pp. 249 - 250.

[2] The fossil fauna of the Wianamatta Shales, as proved by the presence of dwarf types of Unio and by the character of the fish is indicative of lacustrine or lagoon, rather than of marine conditions.

Memoirs, Geological Survey of New South Wales, Palæontology, No. I.

Invertebrate Fauna of the Hawkesbury-Wianamatta Series, by R. Etheridge, Junr.

upon with such awed delight, the vast forest-clad landscape stretches away and breaks up into dark cobalt blue hills, wherein is repeated the same unique scenic character."

A brief description may now be introduced of the physical geography and geology, including the probable mode of origin, of the Blue Mountains as far as at present known.

1. Physical Geography—A. *Boundaries.*—The geographical do not agree with the geological boundaries, the area to which the term Blue Mountains is applied embracing only a small portion of the great geological formation of which the mountains are built. On the west the Blue Mountains are bounded by the well-marked escarpment over which the western railway runs at the Great Zigzag above Lithgow ; on the east they are bounded by a well-marked monoclinal fold crossed by the western railway at Lapstone Hill at the Little Zigzag between Emu Plains and Glenbrook. While the east and west boundaries are sharply defined at the above mentioned localities, they become less and less clear when traced respectively to the north and south of the western railway line, and it is a matter of uncertainty as to where the exact boundary line of the Blue Mountains should be drawn on the south and on the north. The southern boundary line is usually fixed at the valley of Cox's River and that of the Warragamba River ; and the northern boundary at the Capertee valley and Colo valley. [See *Plate* 1.]

The geological boundaries, however, are co-terminous with those of the Hawkesbury series, and extend from the Cambewarra Ranges, near Nowra, on the South, to at least as far as the Liverpool Ranges on the north ; and from the head of the Talbragar River on the west, to probably the edge of the continental shelf, about twenty miles east of the present coast line, on the east, *i.e.*, for a distance of about two hundred miles from north and south, and one hundred and fifty miles from east to west.

B. *Relief.*—Geologically, as well as geographically, this larger area may be divided into three portions, (1) the plateau of the

Blue Mountains proper with the elevated land to the north and south of them, as far east as the monoclinal fold at Lapstone Hill, (2) the plain between Lapstone Hill and the coast, (3) the continental shelf. [See *Plate* 2, diagram 1.]

(1.) The plateau of the Blue Mountains proper consists of a deeply eroded platform of Hawkesbury Sandstone. At the top of the fold at Lapstone Hill the platform attains an altitude of about six hundred feet above the sea, and from here it rises westwards at the rate of about one hundred and sixty feet to the mile. Its greatest elevation on the portion traversed by the western railway being 3,658 feet at Clarence Siding. The plateau rises in conspicuous peaks at Mount Tomah 3,276 feet, Mount Wilson, Mount King George 3,470 feet, and Mount Hay 3,270 feet. The portion of the plateau which has suffered least from erosion, with the exception of the peaks just enumerated, is the ridge known as the Darling Causeway, which for a distance of about thirty miles forms the line of water-parting between the tributaries of Cox's River and of the Grose River. The course of the western railway line and of the main western road, almost exactly follow the trend of this causeway. Westwards the plateau terminates in sheer precipices of sandstone, from two hundred up to nearly 1,000 feet in height, of which Hassan's Walls may be taken as a type. The creeks which drain southerly from this water-parting into the Cox, and those which flow northerly to join the Grose, within a few miles of their sources plunge over sandstone precipices, forming waterfalls of which Govett's Leap, Leura Falls, and Wentworth Falls may be taken as types. From the bases of these waterfalls the creeks find their way among masses of densely wooded talus into more or less wide valleys sloping gently eastwards. Traced a few miles further east the rivers formed by the junction of these creeks become hemmed in by walls of sandstone, which form almost impassable gorges near the spots where the rivers break through the monoclinal fold at the eastern margin of the plateau. This remarkable contraction of the valleys has been commented on by Darwin in

the passages previously quoted, and is due to the geological structure of the district, as will be presently shown.

(2) The plain between Lapstone Hill and the coast consists for the most part of low undulating hills with smooth outlines, seldom attaining an elevation of five hundred feet above the sea, and chiefly composed of clay-shales with strips of alluvial ground. Near the coast, however, the physical features characteristic of the Blue Mountains reappear on a smaller scale, in the shape of bold cliffs and deeply eroded bays and estuaries. The cliffs attain an elevation of from one hundred to two hundred and fifty feet. The southern, western and northern portion of this area is drained by South Creek and the Nepean and Hawkesbury Rivers, while the eastern is drained by George's River and the Parramatta River.

(3) The continental shelf stretches from the coast eastwards to the one hundred fathom line in a tolerably uniform slope of about thirty feet to the mile. From the edge of the continental shelf the sea-bottom descends rapidly to a depth of 2,300 fathoms. [See *Plate* 2, diagm. 1.]

2. Geology—A. *Formations.*—(1) Sedimentary.—*a* The Devonian. Rocks belonging to this formation are exposed at the base of the western escarpment of the Blue Mountains from Capertee to at least as far south as Hartley. They consist chiefly of quartzites, in which the brachiopods *Spirifera disjuncta* and *Rhynchonella pleurodon* abound, and the lamellibranch *Pteronites Pittmani* is not infrequent. The presence of *Lepidodendron Australe* in these rocks was proved by Mr. J. Clunies-Ross, B.Sc., and by Mr. Pittman and myself in 1894.[1]

These rocks graduate upwards into sandy argillites containing *Lepidodendron Australe* in tolerable frequency. Both have been strongly intruded by granite, as is well shown on the section which accompanies Mr. C. S. Wilkinson's geological map issued by the

[1] Rep. Austr. Assoc. Adv. Science, Hobart, 1892, and Rec. Geol. Sur. N. S. Wales, Vol. III., pt. iv., pp. 194–201. By Authority, Sydney, 1894.

Department of Mines in 1878 on the Bowenfels and Hartley district. Downwards this Upper Devonian, or Lower Carboniferous formation, is probably separated, by a strong unconformity, from the Upper Silurian formation, typically developed at the Jenolan Caves and at the Lime-kilns near Bathurst. It is at the former locality that radiolarian jaspers have recently been discovered by me, not far from a well-marked limestone horizon of Upper Silurian Age containing an abundant marine fauna. Evidence for this unconformity has been quoted by Mr. J. Clunies-Ross,[1] and further evidence has been collected by Mr. W. F. Smeeth, some of my geological students and myself, in the neighbourhood of the Jenolan Caves as shown on diagram 1, *Plate* 2 of this address.

b. Permo-Carboniferous system. All the rocks of this system are separated from those of the preceding by a very strongly marked unconformity, gently inclined strata of Permo-Carboniferous being observable in many places, *e.g.*, near Capertee and Rydal, reposing on vertical strata of the Upper Devonian series. Included pebbles of Upper Devonian quartzites, containing *Spirifera disjuncta*, as well as of the granites which have intruded the Devonian rocks, are conspicuous in the basal conglomerates of the Permo-Carboniferous system. The unconformity is still further emphasized by an extensive over-lap of the Upper Marine series, which conceals from view both the Greta Coal-measures and the Lower Marine Series throughout the entire area of Permo-Carboniferous rocks exposed on the western escarpment of the Blue Mountains, as shewn on my section of this district already published.[2]

The six divisions of the Permo-Carboniferous system recognizable in the type-district of Maitland are in ascending order :—

1. Lower Marine Series.
2. Greta Coal-measures.
3. Upper Marine Series.

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[1] Quart. Journ. Geol. Soc., Vol. L., 1894, pp. 108 – 109 and p. 119.

[2] Annual Report, Department of Mines, 1890, p. 254.

4. Tomago (East Maitland) Series.
5. Dempsey Beds.
6. Newcastle Series.

Probably only two are represented in the sections exposed in the Blue Mountains, viz., the Upper Marine series and the Newcastle series This is perhaps due to the fact that the Upper Marine series have overlapped, and so concealed from view, the Lower Marine series and the Greta Coal-measures, and the Newcastle series has overlapped the Dempsey Beds and Tomago series. The rocks of the Upper Marine series consist of basal conglomerates, sandstones, and mudstones containing marine Permo-Carboniferous fossils, and occasionally pyritous mudstones with large boulders up to four feet in diameter. The line of junction between this series and the overlying coal-measures of Lithgow etc., (Newcastle series) is marked by a bed of grit and conglomerate about fifty feet thick, which may be termed the "Capertee grits," this has been referred to by Professor Stephens.[1] Mr. J. E. Carne, of the Geological Survey of New South Wales has also referred to this well marked horizon.[2]

The conglomeratic grit weathers out into over-hanging ledges and cave-like hollows, on the sides and floors of which efflorescences of alum, salt, epsomite, etc., are frequently observed.[3] It forms a conspicuous feature at the base of the western escarpment of the Blue Mountains from Bowenfels to beyond Capertee. Immediately overlying the Capertee Grit is the Lithgow Coal-seam, from one to ten feet in thickness, forming the principal seam worked in the district. This is succeeded by a seam of kerosene shale from a few inches to four feet in thickness, worked economically at Hartley Vale, Katoomba, and Capertee, from which it is separated by about forty to eighty feet of strata. The

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[1] Proc. Linn. Soc. N.S. Wales, Vol. VI , p. 550.

[2] Records Geol. Surv. N. S. Wales, Vol. IV., pt. ii., pp. 39 – 48. By Authority, Sydney 1894.

[3] C. S. Wilkinson—Annual Report Department of Mines, 1877. Geol. Map, Hartley Bowenfels District, Note 26. By Authority, Sydney 1878.

character of these strata and the sequence and thickness of the remaining coal-seams is shown on *Plate* 3.[1] The strata are chiefly composed of clay-shales and soft sandstones with occasional bands of chert, they constitute the lower portions of the cliffs, and occupy considerable areas in the sides and bottoms of the valleys in the western portions of the Blue Mountains. The uppermost seam, formerly worked at Katoomba, is probably identical with the Bulli Coal seam in the Illawarra Coal-field and with the Wallarah seam in the Newcastle series of the Hunter River Coalfield. *Glossopteris*, *Gangamopteris*, *Vertebraria*, and *Brachyphyllum* predominate in the flora.

Traced eastwards the seams of coal dip at the rate of about ninety feet per mile until they disappear at the bottoms of the valleys near the longitude of Lawson, and become covered by the lowest rocks of the overlying series, the Narrabeen beds, the inclination of the beds of the rivers in this portion of the Blue Mountains being less rapid than that of the strata, and in the same direction. The only spot where the coal is visible still further east, near the latitude of the western railway, in the Blue Mountains proper, is, as far as I am aware, at Euroka Farm about ten miles south of Penrith, on the left bank of the Nepean River. At that locality, however, the coal has probably been forced up from a depth of over a thousand feet by the eruptive mass to which it is clinging, as will be described later on. Fragments of bright unaltered coal are also abundant in the Great Volcanic Pipe known as "The Valley," near Valley Heights, Springwood. The coal seams deteriorate somewhat in the direction of Woodford, as proved by the Woodford diamond drill bores, sections of which are shown on *Plate* 3. These are the furthest bores to the east in the Blue Mountains, in which the coal-measures have been proved. Two bores have been made respectively at Breakfast Creek, fourteen miles, and at Euroka Creek, ten miles southerly from Penrith.

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1 See also "Mineral Products, etc., and Description of the Seams of Coal Worked in New South Wales," by John Mackenzie, pls. 20 and 22, plan 11. By Authority, Sydney, 1887.

The respective depths of these bores being seven hundred and thirty seven feet and four hundred and thirty-four feet.[1] That the coal-measures improve in quality, at all events with respect to the top seam, is proved by the Liverpool Bore and by the Cremorne Bores,[2] the latter on the shores of Port Jackson. (*Plate* 3.)

The question here suggests itself, as the seams in the Cremorne Bores are dipping westerly, whereas the dip of the same seams in the Blue Mountains is easterly, so as to form a basin, 'where is the centre of the basin situated'? Probably, I think, in the neighbourhood of Parramatta.

As the seams are rising seawards from the Cremorne Bores at the rate of one hundred and ten feet per mile (see diagram 1 of *Plate* 2), it is obvious that, if these dips continue for many miles seawards, the coal-seams must outcrop, unless covered unconformably by newer formations, in the continental shelf. Obviously, as the top coal-seam at Cremorne is about 2,850 feet below sea-level, and it is rising easterly at the rate of one hundred and ten feet per mile it should cut the surface of the sea, if its outcrop were produced, at a distance of twenty-five and three quarter miles east of the Cremorne Bore, [on the assumption that its inclination is uniform between these points] that is about twenty-three miles east of the entrance to Port Jackson. At this spot, however, according to the Challenger Reports,[3] the depth of the ocean is one hundred and twenty fathoms. This would therefore bring the outcrop six and a half miles nearer the coast, (if the depth at this second locality be the same as at the first), *i.e.*, to sixteen and a half miles from the coast. The depth of the ocean, however,

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[1] Annual Report Department of Mines, 1884, p. 180. By Authority, Sydney, 1885. *Loc. cit.*, 1885, p. 165.

[2] For further description of the Cremorne Bore see Journ. Roy. Soc. N.S Wales, Vol. xxvii., 1893, "Notes on the Cremore Bore," by T. W. E. David and E. F. Pittman, pp. 443 – 465. Also see, Records Geol. Survey N. S. Wales, Vol. iv., pt. i., p. 1 – 7, by E. F. Pittman, Government Geologist and T. W. E. David.

[3] Challenger Reports—Narrative of the Cruise, Vol. i., part 1, p. 463, pl. 26.

at this spot, according to the Challenger Reports *op. cit.*, is eighty fathoms, which would throw the outcrop a little over two miles further eastward, that is to about eighteen miles from the coast, if the seam outcropped in the actual floor of the ocean. It is just possible that it may do so as "hard ground and shells" were reported near this spot by the Challenger, and this "hard ground" may represent an outcrop of the coal-measures. It is much more probable, however, that the outcrop is covered partly by recent, and partly by Tertiary, marine deposits. As Mr. C. S. Wilkinson has remarked, *(op. cit.)* the absence of any marine Tertiary deposits along the costal area of New South Wales, is probably due to the ocean bed in which they were laid down having participated in the supposed subsidence of the coastal area between the Lapstone Hill monocline and the edge of the continental shelf. Marine Tertiary deposits, attaining a thickness of upwards of five hundred feet, partly of Eocene and partly of Miocene age, are developed in Victoria, Southern South Australia, and Tasmania and it is almost certain that conditions favourable for the deposition of similar strata must have obtained in N. S. Wales also during the Tertiary era. The absence, therefore of Tertiary strata from the eastern coast of New South Wales is only to be explained on the hypothesis that they are now submerged. A thickness of perhaps five hundred feet might be assumed for these Tertiary strata, and to this might be added a further thickness of perhaps one hundred feet for Post-Tertiary deposits. If this theory as to the structure of the continental shelf, at the point where the Bulli seam outcrops, be correct, it would follow that the concealed outcrop would have to be located about five miles nearer Sydney than the distance above quoted, that is, it would have to be placed at thirteen miles instead of eighteen miles east of the coast. Obviously any increase in the angle of dip of the coal-seam between the coast and its concealed outcrop would have the effect of bringing the latter still nearer the shore line. It is improbable, however, that the outcrop is nearer than ten miles, or further than fifteen miles from the coast.

c. The Hawkesbury Series can be separated into three divisions, which in ascending order are as follows :—

1. Narrabeen Beds.
2. Hawkesbury Sandstone.
3. Wianamatta Shales.

This series is classed, provisionally, as Triassic, partly on account of its fossil flora in which *Thinnfeldia*, *Tæniopteris*, and *Phyllotheca* predominate ; partly on account of its fossil fauna which numbers *Cleithrolepis*, *Palæoniscus*, etc., amongst its fish, and several species of *Mastodonsaurus* amongst the reptiles, while *Estheria* is very abundant chiefly in the Narrabeen Beds. For descriptions of the fossil flora and fauna the works mentioned below may be consulted.[1]

1. The Narrabeen Beds succeed the Permo-Carboniferous Coal-measures apparently without unconformity in the Blue Mountains; traced, however, to the Hunter River district a distinct unconformity may be observed, in the neighbourhood of the Pokolbin Hills. The existence of this unconformity might have been inferred from the very strong break between the fossil flora and fauna of these Triassic rocks and those of the Permo-Carboniferous system. The Narrabeen Beds consist in their lower portions of sandstones and shales, and in their upper portions purplish-red shales are developed, which, although not more than ten feet or so in thickness, in the western portion of the Blue Mountains, nevertheless form a conspicuous feature in the landscape. If the observer looks across one of the vast amphitheatrical depressions,

[1] Mem. Geol. Sur. N.S. Wales, Palæontology No. 1—The Invertebrate Fauna of the Hawkesbury-Wianamatta Series, by Robert Etheridge, Junr. By Authority, Sydney, 1888.

Mem. Geol. Sur. N. S. Wales, Palæontology, No. 3—Geological and Palæontological Relations of the Coal and Plant-bearing Beds of Palæozoic and Mesozoic Age in Eastern Australia and Tasmania, by Ottokar Feistmantel. By Authority, Sydney, 1890.

Mem. Geol. Sur. N. S. Wales, Palæontology No. 4—The Fossil Fishes of the Hawkesbury Series at Gosford, by A. S. Woodward. By Authority Sydney, 1890.

so charcteristic of this portion of the mountains, the outcrop of this thin bed at once catches his eye in the face of the opposite cliff, shewing as a thin red horizontal line about halfway up the cliff face of yellow sandstone. Near the great Zig-zag, above Lithgow, the Narrabeen Beds have a total thickness of 357 feet; traced eastwards they thicken considerably, until at the Cremorne Bore their thickness amounts to 1,897 feet. The progressive thickening of these beds, especially of the chocolate shales, is shewn on diagram 1, *Plate* 2. Between Sydney and Bulli, about five hundred feet above the level of the Bulli seam, are some gritty and shaly beds, greenish-purple or reddish-purple, containing flakes and minute veins of metallic copper. These are known as the cupriferous tuffs and have been described by me elsewhere.[1]

There can be little doubt that these purple shales, as well as the chocolate shales, represent volcanic tuff deposited in water, and that the metallic copper is derived from the decomposition of basic minerals in the tuff beds. It may here be mentioned that metallic copper occurs in minute veins in a basic lava contemporaneous with the Permo-Carboniferous system at Shoalhaven in the Illawarra district. Pebbles of quartz-felsite, quartzite, etc., from two to four inches in diameter may frequently be observed in these beds near the coast, probably derived from the continental shelf. Calcareous sandstones, shewing Fontainebleau sandstone structure may also be seen in these beds near the coast.[2]

2. The Hawkesbury Sandstone. This division appears to be conformable to the preceding in the Blue Mountains, though there is evidence of a certain amount of contemporaneous erosion along their junction to the north of the Hawkesbury River. Near Mount Victoria, in the western division of the Blue Mountains, the sandstones have a thickness of about two hundred and fifty feet, they are there capped by a bed of pale greenish-grey clay-

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[1] Rep. Austr. Assoc. Adv. Science, Sydney, 1887, Vol. I., pp. 275 – 290. —"Cupriferous Tuffs of the Passage Beds between the Triassic Hawkesbury Series and the Permo-Carboniferous Coal-measures of N. S. Wales."

[2] Journ. Roy. Soc. N. S. Wales, Vol. XXVII., 1893.

shale from which Mr. H. G. Rienitz has collected a great number of fossil plants, many of which belong to forms as yet undescribed. Eastwards the sandstones thicken to their maximum, as proved at the Cremorne Bore, of over 1,020 feet. The sandstone is thick bedded, massive in places, but more frequently shewing diagonal bedding. The angle of dip of the diagonal bedding, if the plane of the true bedding be taken as the datum horizon, seldom exceeds 26°. Mr. C. S. Wilkinson has stated that the prevalent dip of the diagonal bedding is towards the north east. Beds of clay-shale are occasionally interstratified. One of the most persistent of these may be traced, at intervals, from near Blackheath to the monoclinal fold a distance of over twenty miles; it is one to eight feet thick and twenty feet below the top of the Hawkesbury Sandstone. A good section of it is exposed in the railway cutting at the eastern approach to the tunnel, at the top of Lapstone Hill. A short distance east of the Katoomba railway station a large isolated fragment of clay-shale, apparently on the same horizon as the bed just referred to, is seen in the railway cutting, embedded in the sandstone in such a way as to prove that it was contemporaneously tilted out of its original horizontal position.[1] The contemporaneous dislocation of this shale has been ascribed by Mr. C. S. Wilkinson to some kind of ice action.[2] In places, especially towards the upper portion of the bed, the sandstone is loosely aggregated; in the middle and lower portions, however, it is more or less firmly compacted. It is composed of grains of quartz, decomposed fragments of felspar, minute crystals of iron pyrites, and, as recently shown by Mr. H. G. Smith, of red garnets.[3] Crystals and small veins of barytes may occasionally be noticed. Scales of graphite appear to be uniformly distributed in considerable quantity throughout the whole mass of the sandstone; no satisfactory explanation of their presence has as yet been offered.

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[1] Journ. Roy. Soc. N. S. Wales, Vol. XIII., 1879, pp. 105 – 107.

[2] Contemporaneously contorted diagonal bedding, like that seen at Coogee, near Sydney, may be due to similar agency, as suggested by me elsewhere.—Quart. Journ. Geol. Soc., Vol. XLIII., pp. 190 – 196.

[3] Journ Roy. Soc. N. S. Wales, Vol. XXVIII., 1894, pp. 47 – 50.

Both Darwin and the Rev. W. B. Clarke comment upon the highly crystalline character of the sand grains in the Hawkesbury Sandstone; the individual grains are distinctly faceted, owing to the development of secondary quartz crystals, with brightly reflecting faces, around the original sand grains. Several bores for water in this sandstone prove it to be, generally, impervious.

The Hawkesbury Sandstone is traversed by numerous joints. These are frequently infilled with hydrated peroxide of iron derived from the decomposition of the pyrites crystals, or from the alteration of protoxide of iron. The existence of the joints much facilitates the work of erosion of these sandstones, and accounts for the frequent smooth and vertical faces of rock in the cliff sections. Though whitish-grey at a depth, the sandstone weathers various shades of yellow and rusty to reddish-brown near the surface, the weathering frequently assuming the form of concentric shells stained different colours by iron oxides and producing very characteristic features in the superficial structure of the Blue Mountain plateau.[1]

The Hawkesbury Sandstone has yielded the following fossil plants, *Thinnfeldia*, *Gleichenites*, *Phyllotheca*, *Ottelia* (?), *Equisetum* etc. The fossil fauna includes a *Palæoniscus*, which was found at Biloela at a depth of sixteen feet below the sea level; close to the same spot were subsequently discovered the thoracic plate of a *Mastodonsaurus*, *M. platyceps*, W. Stephens,[2] and a *Gasteropod*, *Tremanotus Maideni*. The latter forms the only example of a marine fosil hitherto discovered in the Hawkesbury Sandstone, and is a remarkable instance of a survival in the Southern Hemisphere, in Triassic time, of a form which had become extinct in the Northern Hemisphere, apparently at the close of the Silurian

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[1] Mr. W. A. Dixon informs me that he thinks it not improbable that the iron in the unweathered portions of the Hawkesbury Sandstone is present in the form of protoxide in combination with organic matter other than the graphite scales already referred to.

[2] Proc. Linn. Soc. N. S. Wales, Vol. I., (Series 2nd) 1886, pp. 931, and 1175 - 1192, pl. 22.

period. Reference is given below to a description by R. Etheridge Junr., of this interesting fossil.[1] A fossil fish, *Cleithrolepis*, has been found in the Hawkesbury Sandstone at an altitude of 3,450 feet near Katoomba (?).[2]

3. Wianamatta Shale. Of this formation, which probably at one time covered a considerable area on the Blue Mountains, only a small portion is left undenuded. The westernmost extension of these shales is probably at a point about halfway between Linden and Faulconbridge. At Springwood the shales attain a thickness of about eighty feet, and, further eastwards are completely denuded away at intervals, until the monocline at the top of Lapstone Hill is reached. They form a thin capping near the top of the monocline and thicken out rapidly at its base in the valley of the Nepean. They occupy almost the whole of the surface area between Penrith and Sydney, and extend northwards at least as far as the Kurrajong Heights, and southwards beyond Sutton Forest. The Rev. W. B. Clarke estimated their maximum thickness at eight hundred feet; he called them Wianamatta Shales, from Wianamatta the native name for South Creek. The junction of these shales with the underlying Hawkesbury Sandstone is frequently marked by contemporaneous erosion. The shales are dark grey to bluish-grey at a depth, owing to the presence of iron, probably as protoxide, and carbonaceous material. Near the surface where they have been weathered, they have become bleached through the aggregation of the iron into segregation-veins and nodules of hematite and limonite, and the removal of some of the carbonaceous material. Bands and nodules of clay ironstone occur on certain horizons, especially near the base of the series, and thin seams of coal have been described in the upper beds of these shales. Mr. Clarke states that one of these seams with its clay bands, at South Creek, has an aggregate thickness of four feet.

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[1] Annual Rep. Dep. Mines, 1886, pp. 174 – 176, pl. appendix N., f. 1 – 3.

[2] Remarks on the Sedimentary Formations of New South Wales. By Rev. W. B. Clarke, Fourth Edition, 1878, p. 70.

Mr. E. F. Pittman informs me that he has measured a seam of coal over nine inches in thickness in these shales at Bankstown. Lenticular beds of argillaceous limestone occur sparingly; one of these has been worked for the manufacture of Portland Cement by Messrs. Goodlet and Smith near Granville; another, on a higher horizon forms the capping of a lofty ridge at Badgelly Trigonometrical Station to the west of Campbelltown. Vanadic oxide has been recorded as occurring in these shales.

In the railway sections between Penrith and Sydney the shales exhibit folding and faulting on a small scale, due, I think, rather to an expansion of the shales through weathering than to deep-seated disturbances. This is proved by the fact that these folds and faults may be observed to completely disappear downwards as they approach the surface of the underlying Hawkesbury Sandstone; they are, in fact, what may be termed expansion folds and expansion faults. In their upper portions the Wianamatta Shales become arenaceous, and towards Mittagong assume a chocolate or reddish purple colour, which makes them (in hand specimens) almost indistinguishable from the chocolate shales of the Narrabeen Beds. Barytes [f. H. G. Smith] occurs in these shales as well as in the Hawkesbury Sandstone.[1]

Fossils are most abundant near the base of the Wianamatta Shales, where they are preserved in concretions of clay ironstone. Dwarfed types of the Unionidæ are very abundant in places; they have been collected chiefly by Mr. B. Dunstan, and have been referred by Mr. R. Etheridge Junr. to the following species:—*U. Dunstani*, *U.*(?) *Wianamattensis*, *Unionella Carnei*. *U. Bowralensis*. A small *Mastodonsaurus* was discovered also by Mr. Dunstan, at the Gib Rock tunnel near Bowral; and lately a gigantic specimen, probably referable to the Mastodonsauridæ, and measuring not less than ten feet, was found by him in a large ironstone concretion at the St. Peter's brickpits near Sydney. He has also, by systematic and industrious collecting, lately brought to light a large collection of fossil fish, as yet undescribed. The following

[1] Proc. Linn. Soc. N. S. Wales, (Series 2nd) Vol. II., pt. 2, pp. 131 – 132.

fossil fish have already been described *Palæoniscus*, *Cleithrolepis*. Mr. John Mitchell of Narellan has recorded the occurrence of the elytron of a fossil *Buprestid*, from the Wianamatta Shales near Campbelltown. The Rev. W. B. Clarke states that *Entomostraca* are also met with in the shales. Fossil plants are tolerably abundant, and comprise chiefly the following forms:—*Thinnfeldia odontopteroides*, *Macrotæniopteris Wianamattæ*, and *Phyllotheca*.

d. Cretaceous or Tertiary (?). At the top of the monoclinal fold, between Lucasville and Glenbrook, a deposit of coarse river gravel rests on an eroded surface of Hawkesbury Sandstone, just below the horizon of the junction line of the Hawkesbury Sandstone with the Wianamatta Shale. The position of this river gravel is shewn on a geological map by the Rev. W. B. Clarke at the commencement of the fourth edition of his work, "Sedimentary Formations etc. of N. S. Wales." Its trend follows approximately that of the modern valley of the Nepean, and it may probably be correlated with the somewhat similar gravel seen in the railway cutting east of and close to St. Mary's. This gravel deposit, together with the old river channel in which it is reposing, follows the bends of the monoclinal folds in such a way as to prove that the fold did not exist at the time when this gravel deposit was formed. This is a very significant fact in the history of the physiography of the Blue Mountains, inasmuch as it proves that at the time this river was flowing, the deep gorges, such as those of the Grose and Cox's Rivers, did not exist, as the surface of the Hawkesbury Sandstone at this time had been eroded to a depth of only a few feet. Had they existed, it would obviously have been impossible for such a river to have co-existed and crossed these gorges at right angles, at an altitude of over five hundred feet above their present beds. This single fact at once disposes of the surmise of Darwin, that the valleys of the Blue Mountains occupy the sites of original depressions in the sandstone platform. The river gravel, at the spot where the tunnel of the western railway runs beneath it, is about one hundred and fifty yards wide and fifteen to twenty feet thick; the shingle varies from a

few inches up to over a foot in diameter, and is composed of very much the same kind of rocks as those in the recent gravels of the Nepean. The sandy matrix in which they lie is compacted in places into a fairly coherent rock ; and I should think it probable that this river channel dates back at least to the Miocene or Eocene period. The determination of its exact geological age would be of great importance ; there can be little doubt that the river which formed it was an ancestor of the Nepean, and probably therefore the chief drainage channel of the Blue Mountains in that age.

e. Pleistocene (?). A formation, presumably of this age, is developed chiefly in the valley of the Nepean, between Mulgoa and Richmond ; and consists of a terrace of red sandy soil, overlying gravels, the surface of which is about twenty feet above the level of the highest modern floods. (See diagram 2, *Plate* 2.) No determinable fossils have, so far as I am aware, been found in it.

f. Recent Alluvial. Formations of this age are developed chiefly in the Nepean and Hawkesbury valleys, in the estuaries of the Hawkesbury, the Parramatta River, George's River, etc. An observer contemplating the vast sheets of alluvial gravels, forming the plains of Mulgoa, Penrith, Windsor and Richmond, cannot fail to appreciate the vast erosive force, that must have been exercised by the Nepean River and its tributaries, to transport such a bulk of rock material through their narrow gorges, some of which has been carried for a distance of perhaps over fifty miles. From Mulgoa to Richmond, the alluvial gravels vary from one to two miles in width, and extend in an unbroken sheet about twenty miles long. Their thickness is at least forty-seven feet. The iron piers for the Penrith Railway Bridge over the Nepean are sunk a few feet below the bed of the river in gravel, the base of this gravel is forty feet above sea level. If the bulk of the Pleistocene gravel be added to that of the recent alluvial gravel it will amount approximately to about thirty square miles ; and those who depreciate the erosive power of the rivers of the Blue Mountains, should not forget that almost the whole of this grave

has been swept through the narrow gorge of the Nepean, where it debouches from the Blue Mountains, about three miles above Penrith.

An interesting feature in connexion with these recent alluvials is the fact that they appear to descend far below sea level, which confirms the theory that the coastal strip has subsided to a depth of two or three hundred feet, and so has enabled the waters of the Pacific to inundate the valleys of the Hawkesbury and the Parramatta rivers for a considerable distance inland from their original seaward terminations. That these alluvials in the estuary of the Hawkesbury extend considerably below sea level, was proved by the excavations and trial borings made along the line of the present Hawkesbury River railway bridge. The deepest of these borings penetrated to a depth of one hundred and seventy-six feet below sea level, without completely passing through the alluvial deposits. The water of the estuary was here found to be fifty feet deep; the thickness of the alluvials at this spot would therefore be at least one hundred and twenty-six feet. No absolute proof however, was obtained that the lowest alluvials in this estuary were distinctly of fluviatile and of fresh-water origin; but as already stated, the lowest alluvials were not reached in the borings. It would be very important to ascertain whether coarse river gravels do not there underlie the estuarine clays; and if any shells of *Unio* or *Cyclas* were discovered, *in situ*, in these alluvials, their original fluviatile origin might be looked upon as proved. The borings for the iron piers of the Parramatta railway bridge also show that the alluvials extend there for a considerable depth, eighty-nine feet, below sea level, the alluvials being at least sixty-three feet thick. The diamond drill bores for coal at Narrabeen Lagoon struck a bed of peaty loam fifteen feet in thickness, at a depth of over twenty feet below sea level; and a well marked layer of marine shells at over eighty feet below sea level. Both these occurrences are strongly in favour of the hypothesis that either the coastal area here has sunk, or the sea level has risen to the amount of twenty or eighty feet at least, in late geological time.

It would be most useful, if engineers and others, would keep accurate records of any sections obtained in borings or excavations in these alluvials, especially in cases where they descend below sea level.

(2) Eruptive rocks. These may for convenience be divided into (A), a Pre-Triassic Group older therefore than the Blue Mountains, and (B) a Post-Triassic Group of later origin than the formations of the Blue Mountains.

(A) *Pre-Triassic*—(i.) Granites. These rocks are represented chiefly by granites, which are seen outcropping to the west of the Megalong Peninsula, near Katoomba, and which extend thence into the valley of Cox's River, and occupy considerable areas near Hartley, Rydal, etc. They are biotite granites, rendered porphyritic in places by orthoclase felspar. These granites are probably of the same age as those of Bathurst, which have already been described by the Rev. J. Milne Curran. At the latter locality they are rich in sphene. As already mentioned these granites near Rydal have intruded the *Lepidodendron* beds, but no evidence has as yet been adduced to show that they intrude the Permo-Carboniferous rocks in the Blue Mountain region. On the other hand, near Hartley and Marangaroo, granite pebbles may be noticed in the basal beds of the Permo-Carboniferous System. (See *Plate* 2.)

(ii.) Diabasic Lavas. Sheets of eruptive rock, apparently of contemporaneous origin with the Upper Marine Series, are seen in the railway cuttings between Rylestone and Lue, especially near the Rawdon Coal Mine. They may have been erupted contemporaneously with the great series of andesitic dolerites and tuffs of the same geological age at Kiama.

(iii.) Tuffs of a basic character, and dipping at a steep angle, occur high up on the western escarpment of the Blue Mountains, at Cumberamelon, on a horizon about midway between the Lithgow Coal-seam and the seam at the top of the Permo-Carboniferous Coal-measures. They somewhat resemble the tuffaceous beds

which overlie the kerosene shale at Doughboy Hollow, north of Murrurundi. It is doubtful, however, whether they are contemporaneous with the Permo-Carboniferous Coal-measures.

(B) *Post-Triassic.* With the exception of an eruptive boss of trachytic syenite near Mittagong, which is outside of the Blue Mountains proper, all the Post-Triassic eruptives belong to the basic group. Mounts Wilson, Tomah, King George, and Hay are capped with outliers of basaltic lava, as shewn on the geological map of the Rev. W. B. Clarke, at the beginning of his work on the "Sedimentary Formations of N. S. Wales." As yet, as far as I am aware, scarcely anything is known about these outliers, and it would be a very useful work to map in their boundaries and describe them. At the Australian Kerosene Company's Mine below Hartley platform a basic rock has intruded, and has considerably altered, in places, the kerosene shale, becoming bleached almost white in the process. Further east and situated close to the upper fold of the monocline are two very remarkable masses of volcanic breccia. The smaller mass is situated at Euroka Farm about five miles south of Penrith, and about half a mile west of the left bank of the Nepean River. (See *Plate* 1 – 3.)

It is nearly circular in shape, about one-quarter mile in diameter and forms a depressed area, being completely surrounded by Hawkesbury Sandstone. The latter has been slightly altered along the contact zone. Evidence of the intrusive nature of this volcanic breccia is afforded by the fact that on the north margin a seam of coal, discovered in 1885, was found when followed down in a shaft to be almost vertically inclined in the manner shewn on diagram 2 of *Plate* 3, and to end abruptly at about seven feet below the surface. It was possibly a large disrupted fragment floated up by the volcanic rock from the coal-measures about 1,400 feet below, or perhaps derived from a thin seam of coal in the Hawkesbury Sandstone. The coal shewed very little sign of having been altered. The volcanic breccia is a tough black rock, the base of which is very opaque even in thin slices, and containing

abundant small angular fragments of decomposed dolerite and sandstone, together with numerous sand grains.

About twelve miles north of this mass is a second and much larger development of a similar rock at The Valley near Springwood. This mass has been described by Mr. C. S. Wilkinson[1] as follows :—"In the bottom of a gully called the Valley about one mile from Springwood, there outcrops a mass of altered conglomerates containing fragments of carbonized wood. I did not discover any fossils to enable me to discover the age of the beds ; but in their lithological character they resemble the Lower Coal-measures of the Hunter River. * * With these conglomerate beds occur some trachytic rocks, and in one place there is a spring deposit about fifty feet in diameter of brown iron ore." A cursory examination of this mass by myself a few days ago shews that it is oval in shape about three-quarters of a mile in diameter from east to west, and nearly half a mile from north to south. Towards the centre a good section is seen of the eruptive rock which is there a very hard volcanic breccia, similar to that already described at Euroka Farm. Crystals of augite up to three-quarters of an inch in diameter are abundantly distributed throughout the mass, and fragments of very slightly altered bituminous coal, from a fraction of an inch up to three inches in diameter, are very abundant in places. There is evidence of an older and newer breccia as fragments of the older breccia may be noticed in places enclosed in the newer. The intrusive character of the mass is proved by the vertical position of large fragments of sandstone and their alteration near the north-east edge of the intrusion. The surrounding Hawkesbury Sandstones are almost horizontal. The Valley forms a flat-bottomed depression about five hundred feet below the level of the top of the surrounding Hawkesbury Sandstone, and five hundred and fifty feet above the level of the sea. It is difficult to decide as to the exact part which these eruptive masses at the Valley and at Euroka Farm have played in the basic eruptions which visited this district in Post-Triassic

[1] Annual Report, Mines Department, 1882, p. 139.

time. The evidence is tolerably clear as to their having intruded the Hawkesbury Sandstone as well as the coal-measures, and as to there having been a powerful upward flow of paroxysmal violence. At first sight, therefore, one would infer that they mark the site of old volcanic chimneys. This was probably their function, though the slightly altered condition of the fragments of bituminous coal seems incompatible with an intimate association with a matrix of volcanic rock. The highly brecciated character of the mass, however, shews that superheated water producing violent steam explosions was probably abundantly present, and this may have protected the coal from calcination such as it has undergone when in contact with the basic dykes at Cremorne. There is here, therefore, a fine field for further investigation.

About twenty miles east of the Valley is a large eruptive mass of very coarse dolerite at Prospect Hill (Waimalee). The Rev. W. B. Clarke,[1] has referred to this mass :—"At Waimalee on Prospect Hill, west of Parramatta, the magnetic diorite which there occurs, and which is, probably, the summit of a concealed mass submerged during the Carboniferous period and belonging to the Auriferous Epoch, has furnished the material of fern bearing beds of this division, that rest upon the diorite, and have since been intruded into and altered by basalt, which, in another part of the hill, exhibits a columnar structure." This so-called "magnetic diorite" is now known to be a crystalline-granular dolerite rich in titaniferous iron and analcime. Drusy cavities, one to four feet in diameter, are occasionally met with, having their sides lined with prehnite. The dolerite graduates into the basalt, and there is clear evidence that both have intruded the overlying Wianamatta Shales, which in places are converted into chert at the point of contact. No trace of any breccia has yet been noticed. Probably this mass which is over half a mile in diameter represents the material which has consolidated in the reservoir of a now deeply denuded volcano. About ten miles

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[1] Researches in the Southern Goldfields of N. S. Wales, Second Edition Sydney, 1860, p. 248.

north-easterly from the preceding is the much smaller volcanic pipe (?) which has been worked for road-metal at the Pennant Hills quarry. This quarry has been described by Mr. C. S. Wilkinson.[1] It has also been described by Messrs. W. F. Smeeth, J. A. Watt, and myself.[2]

It is an oval mass of basalt about one hundred yards in greatest diameter, and has obviously intruded both the Hawkesbury Sandstone and the Wianamatta Shale. A remarkable feature in connexion with this pipe is the occurrence of blocks of a rare chromite rock adhering to the sides of the basaltic pipe and having a diameter of from six inches to twenty inches. They are irregularly rounded, probably through partial fusion in the basaltic magma, and consist of chrome-diallage, chromite, and a felspar of the lime-soda series.

In addition to the bosses mentioned above, the rocks of the Blue Mountains and the coastal strip are traversed by a network of basic dykes. These have been described by the Rev. W. B. Clarke,[3] by myself,[4] by Mr. E. F. Pittman,[5] and by the Rev. J. Milne Curran.[6] The last mentioned is the only detailed petrological account of these dykes that has yet been published, and is well illustrated. The mineral sodalite is stated to be present in this basalt, and the analyses shew that the total soda = 7·34%. These basalt dykes at Bondi, at La Perouse, at Lane Cove, at Five Dock etc. have rendered the Hawkesbury Sandstone distinctly prismatic (*v. Plate* 9, *op. cit.*) As regards the age of the eruptive rocks described above, while it is clear that they are all Post-

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1 Annual Report Department of Mines for 1879, p. 218, Appendix A.

2 Journ. Roy. Soc. N. S. Wales, Vol. xxvii., 1893, pp. 401 – 406.

3 Transmutation of Rocks in Australasia—Trans. Phil. Soc. N.S. Wales 1862 – 1865, p. 294 *et seq.*

4 "Notes on some points of basalt eruption in N. S. Wales"—Geol. Soc. Aust., Vol. i., part i., p. 25, Melbourne, 1886.

5 "Report on Site for a New Bore at Cremorne."—Annual Report Department of Mines for 1892, pp. 109 – 111.

6 "Structure and Composition of a Basalt from Bondi."—Journ. Roy. Soc. N. S. Wales, Vol. xxviii., 1894, pp. 217 – 231, pls. 9 – 12.

Triassic, as they are distinctly intrusive into the rocks of the Hawkesbury series, it is not quite clear that they are all of the same age. It is probable, that in view of the considerable amount of denudation to which they have been subjected, they date back into some early portion of the Tertiary, or some late portion of the Mesozoic era. For example, the basaltic cappings of Mounts Wilson, Tomah, King George, and Hay, have probably at one time formed part of a more or less continuous sheet; whereas now the Mount Hay outlier is separated from that of Mount King George by the valley of the Grose River, considerably over 1,500 feet deep. No section has as yet been observed shewing any of the eruptive rocks in contact with the ancient river gravels such as those of Lapstone Hill; but it is probable that the eruptive rocks are newer than the gravels. More information on the age of the eruptive rocks is much needed.

C. *Folding*. No important folds have as yet been observed in the Hawkesbury series with the exception of the monocline at Lapstone Hill. Foldings however, on a small scale, may be observed at many places, as seen in the railway cuttings, in the Wianamatta Shales between Lapstone Hill and Sydney. These smaller folds are evidently partly the result of superficial expansion of the shales, due to weathering, as shewn on *Plate* 2, diag. 3. The Lapstone Hill monocline has not yet been systematically traced to its north and south limits. Southwards it certainly extends for at least three miles, and perhaps continues to beyond Picton, a distance of thirty-three miles south. Northwards it extends at least as far as the Kurrajong, and may perhaps be prolonged so as to join the end of the great anticline south of Maitland. Its trend is thus almost meridional. It may be divided into three parts, a fold, a septum and a trough; though there is of course no hard and fast line between the three. As previously stated the sandstone platform has a constant inclination from Clarence Siding to Glenbrook of about ninety-five feet per mile. At Glenbrook, however, the strata rise to the extent of about fifty-three feet eastwards, as shewn on *Plate* 2, diagram 2, and thus form

the gentle western slope of the fold. The summit of the fold is reached at the point where the old line of railway above the Zigzag intersects the ancient river gravels. From here to the top of the Zigzag the strata resume their easterly dip, which increases rapidly until at the point where the septum is reached it amounts to 30°, and near the base of the septum to 50°. The exact shape of the fold has been determined by studying the bending of the well marked bed of clay shale interstratified with the Hawkesbury Sandstone about twenty feet below its surface. There is no evidence that shearing has taken place either in the fold or in the septum. The septum is about fifteen chains long, and the strata composing it dip at an average angle of 38°, the dip of the current bedding being as high as 70°, measured from the present horizon, but never making an angle of more than about 26° with the true bedding planes. (See diagram 2, *Plate* 2.)

The section above referred to, shews how the ancient river channel has partaken in the folding. Near the foot of the escarpment the septum becomes united to the trough; and here again, up to the present I have not been able to find any evidence of shearing. The fact that brittle rocks such as the Hawkesbury Sandstones have been bent so sharply and to such an extent without any considerable fracturing, suggests that the bending movement was probably extremely slow. As regards the amount of displacement which has resulted from the folding, it is found that if the normal easterly slope of the sandstone platform be produced over the bottom of the trough near Emu Plains, the surface of the Hawkesbury Sandstone is about two hundred and fifty feet below its normal level. The question here suggests itself —has the movement produced an upheaval of the eastern escarpment of the Blue Mountains, or a depression of the coastal strip, or both? If positive elevation has resulted, evidence of such should be afforded by a lessening of the easterly slope of the Blue Mountains as it approaches the top of the fold, so as to make the surface to the west of the fold slightly concave. Such a concavity exists, but only to a very limited extent; on the other hand there is a

marked concavity in the trough of the fold which appears to me to point to a positive downward movement of this part of the earth's crust with regard to sea level. The evidence for a submergence, in Tertiary or Post-Tertiary time, of the coastal strip is strong, though it is just possible that this may have been due to a rise in the level of the ocean consequent on the removal of the great ice-sheets of the northern hemisphere at the close of the glacial epoch. The fact is worthy of notice, that the trend of the fold is not at right angles to the greatest diameter of the area of sedimentation, as one would have expected to have been the case had the fold resulted from expansion due to the rise of the isogeotherms. The movement was probably connected with the widespread one which determined the outline of the Australian coast in Tertiary time. (See *Plate* 4.)

D. *Sculpture*. Sufficient evidence has already been adduced to prove that the valleys of the Blue Mountains have been formed through sub-aerial erosion, and do not owe their shapes or positions to any original depressions in the sheets of sediment out of which they were formed, or to marine erosion. Had the sea played any part in their erosion there could not fail to have been some traces left behind of raised beaches: no vestige of such have as yet been discovered in the Blue Mountain area. As already noticed by Darwin, the valleys are somewhat funnel-shaped, being wider westwards and narrowed eastwards to deep gorges with precipitous sides. This structure is related to that of the geological morphology of the region. In the westward portion of the Blue Mountains the soft strata of the coal-measures which underlie the sandstones of the Hawkesbury series stand high, and have thus been much exposed to denudation, and have led to a constant undermining of the sandstones wherever these softer rocks have been brought within reach of denuding agencies. As, however, the soft strata of the Permo-Carboniferous coal-measures dip eastwards at a more rapid angle than the river channels, which also flow eastwards, it follows that in the east portion of the Blue Mountains the rivers leave the strata of the coal-measures and flow

over the hard sandstones of the Hawkesbury Series, so that no undermining action is possible in the eastern area; hence the narrowness of the river gorges near the eastern escarpment. With reference to the date when the erosion of the present valleys of the Blue Mountains commenced, it must obviously have been later than that of the basaltic eruptions of Mounts Hay and King George, and later than that of the ancient river channel at Lapstone Hill. The last two dates were perhaps late Mesozoic or early Tertiary. Whatever may be the date of the commencement of the formation of the fold, it is clear that that of the erosion of the valleys of the Blue Mountains must have nearly coincided with it. The depth of the valleys exceeds 1,500 feet.

E. *Relation of the Blue Mountains to the leitlinie of Australia.* On *Plate* 4 are shewn the guiding lines of folding which have determined the principal orographic features of Australia. There is no evidence that in Pre-Cambrian, Cambrian, and Silurian time the eastern boundary of Australia approximated to its present outline. In Carboniferous time, however, an extensive folding took place (termed the 'Gympie folding' on *Plate* 4) which led to the development of the eastern cordillera of Australia, as elsewhere suggested by me.[1] That the bulk of this folding was accomplished in Carboniferous time is proved by the fact that whereas the Carboniferous strata have been powerfully folded over wide areas, the Permo-Carboniferous rocks have been very little disturbed. The trend of the Blue Mountain fold approximately follows that of the present coast line as well as of the continental shelf; and it therefore, perhaps, represents a renewal on a small scale in Mesozoic and Tertiary time of the folding so strongly marked in the Carboniferous strata of Australia.

Summary.—There is evidence that a few miles to the west of the present western escarpment of the Blue Mountains, marine conditions obtained in Upper Silurian time, from at least as far south as the Monaro tableland to beyond the Jenolan Caves,

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[1] Proc. Linn. Soc. N. S. Wales, Vol. VIII., Series 2, Nov. 29, 1893, pp. 582–597, and pls. 27 and 28.

Bathurst, and Mudgee. That this sea may have been of considerable depth, is perhaps implied by the development of radiolarian cherts near the Jenolan Caves. Folding and elevation ensued, and in Upper Devonian time there was heavy sedimentation prolonged into Carboniferous time. While the conditions were still mostly marine the frequent occurrence of interstratified beds of conglomerate shews that land was not far distant to the west of the present position of the Blue Mountains. The greater portion, however, of the present New England tableland may have been covered by a very deep ocean, as would appear from the very extensive development of radiolarian red jaspers in that district. Then followed the powerful folding of the Carboniferous (Gympie) and Upper Devonian formations, a great land-building epoch in the history of the Australian continent. When this folding had nearly ceased, and a great range had now become established west of the present site of the Blue Mountains, sediments derived from the former began to be deposited in the shallow seas extending from near Penrith to the continental shelf. These constituted the strata of the Lower Marine Series (Permo-Carboniferous). Swampy or lacustrine conditions succeeded, and the Greta coal-measures were laid down over an area about two hundred miles long from north to south, by from thirty to forty miles from east to west. A considerable subsidence ensued during which the waters of the Pacific penetrated to at least as far inland as Mount Lambie, about seventy-two miles inland from the present coast. The subsidence amounted to a maximum of about 5,000 feet in the Maitland district, 2,500 feet in the Illawarra district. The strata of this epoch belong to the Upper Marine Series. The cessation of the subsidence was accompanied by volcanic eruptions most extensively developed in the Kiama neighbourhood, but represented also on a smaller scale by the volcanic rocks near Rylstone. Swampy conditions returned on a larger scale than ever, and the Bulli-Newcastle coal-measures were formed in the Blue Mountain area; while in the Newcastle area a middle group of coal-measures (The Tomago Series) was developed as well, being

interstratified between the top of the Upper Marine Series and the base of the Dempsey Beds, which underlie the Newcastle coal-measures. The abundance of fossil trees referable to *Arau carioxylon*, many preserved in the form of stumps *in situ* in the formation in which they grew, is clear proof that the conditions under which the Newcastle-Bulli coal-measures grew were terrestrial rather than marine. The formation of the last of the coal seams of the Newcastle-Bulli Series closes the history of the Palæozoic era in New South Wales.

Triassic time witnessed the deposition of the sediments of the Narrabeen Beds, partly lacustrine or estuarine, partly of volcanic (tuffaceous) origin. The entire absence of distinct marine fossils in these beds, and the abundance of remains of terrestrial plants and *Estheria*, suggest that the conditions were lacustrine or fluvio-marine. The sands and conglomerates of the Hawkesbury Sandstones were next formed under conditions probably similar to those just described, but there is no evidence of any important tuffaceous beds in this group. The material of which it is formed was derived from Plutonic rocks to a considerable extent; and the currents which carried it came chiefly from south-south-west, so that it may be inferred that high land lay in that direction. A slight elevation appears to have followed, and the clays of the Wianamatta Shales were next formed in a brackish lake of much smaller dimensions than the area covered by the Hawkesbury Sandstones. The Wianamatta Shales conclude the Triassic system of New South Wales. There is no evidence to shew that any strata were added to the Blue Mountain area, or the present coastal strip, in Jurassic or Lower Cretaceous time. A slight upward movement, however, of the western portion of the Blue Mountains appears to have been in progress whereby the upper Marine Beds of Mount Lambie were elevated to a height of over 3,500 feet above the sea. At the close of the Mesozoic, or commencement of the Tertiary era, a large river flowed from south to north at the top of what is now Lapstone Hill, so that the erosion of the eastern portion of the Blue Mountains could not have fairly commenced at this

time, as that ancient river had only just succeeded in cutting its channel down to the level of the top of the Hawkesbury Sandstone. Then followed the gradual folding of the earth's crust along the Lapstone monocline, accompanied by more or less extensive volcanic eruptions, in the neighbourhood of Prospect, Pennant Hills etc., in the coastal strip, and The Valley, Euroka Creek etc. in the Blue Mountains. The erosion of the lower portions at any rate of the valleys of the Blue Mountains dates from the formation of the monocline, since which time they have been deepened to the extent of six hundred feet or more. While the monocline was forming the coastal strip was slowly subsiding ;. and in the now submerged valleys along the seaward margin of this strip were laid down the sands and gravels successively of Pleistocene and Recent Age. It would be of importance to ascertain by means of accurate measurements whether the subsidence is still in progress. My thanks are specially due, for information supplied me for this paper, to the following :—T. F. Furber, L.S., H. Deane, M.A., M.I.C.E., F.L.S., W. S. Dun, and A. J. Prentice, B.A.

Notes.

1. It is stated in this address that the Sandstone plateau of the Blue Mountains attains an elevation of about 4,000 feet. It is questionable, however, whether any portion of the Blue Mountains proper attains a greater elevation than about 3,800 feet.

2. While the proofs of this address were being revised, I have been able to obtain further evidence which shows that the coal, disrupted by the volcanic neck at Euroka Farm, (Diagram 2, *Plate* 3) was probably derived from the Hawkesbury Sandstone rather than from the Permo-Carboniferous coal-measures.

On PERIODICITY of GOOD and BAD SEASONS.

By H. C. Russell, B.A., C.M.G., F.R.S.

[With Plate V.]

[*Read before the Royal Society of N. S. Wales, June 3, 1896.*]

I FEEL some reluctance in coming forward to night, with the results of my investigations into the periodicity of good and bad seasons—floods and droughts if you will—because they must come to you as a surprise, and they will make a claim on your confidence, which at first sight you will probably not be disposed to grant. For myself, I know that some years ago, if anyone had come to me, stating that it was possible to forecast the seasons many years in advance, I should have received the statement with incredulity. It will not be a surprise therefore if you feel the same, but I hope you will give me a fair hearing before coming to a conclusion, so that you may have before you the evidence that has convinced me, and you can then form your own opinions.

I am not unaware of the fact, that there is a great gulf between having enough evidence to convince oneself, and being able to produce enough evidence to convince an audience, but the statement has not been made until there seemed to me to be evidence enough to convince anyone who will carefully weigh it. Moreover an endeavour has been made to put the evidence in such a form that it can be easily followed by all; to me it seems to be conclusive, but probably most of those who hear, will wait to be convinced by the result of the forecasts, and to meet this very natural feeling there will be to night a forecast of the seasons for the coming two years. The difficulty in getting the facts together has been very great, I have had to ask from history records of passing phenomena, which it has been the habit of the historian to neglect; however, there will be before you a mass of evidence in support of my proposition, *that there is a periodicity in weather.*

The argument of my paper is, that if we take one hundred years of climate thoroughly studied, so that its salient features are clearly defined, and we compare this section of time with all past time, so far as the data are available, and find that the salient points in our century are repetitions of the salient points in all past time, and probably in all countries, then one is justified in coming to the conclusion that these salient points are definitely connected with the climate of the world, and will appear again regularly in the future. The weak point is freely admitted, viz., that history has not kept a regular and continuous account of droughts, but only recorded them when they became very prominent. The strong point is that all the data that history does give us is in favour of the nineteen years' cycle.

In 1876 I read a paper before this Society on Meteorological Periodicity, and pointed out that, of many cycles discussed, one of nineteen years seemed to represent the seasons in New South Wales better than any other. Since that time the subject has been constantly before me, and no opportunity of putting together facts which might be useful in the further dicussion of it has been lost. Scores of investigations have been carried out, some successful, others not so, in bringing forward evidence. My papers to this Society on "Floods in the Darling" and "Floods in Lake George," and the careful study of the rainfall and general weather and the diagrams of various weather records, barometer, thermometer, wind direction and force, and rainfalls of different Australian latitudes, from 1840 to 1887 have all been helps. All the usual weather cycles have been carefully studied, one that very many meteorologists accept, "Sun Spots," will be referred to later.

And it may be explained that the word drought is not used here in the sense in which it is often used in England and elsewhere, that is, to signify a period of a few days or weeks, in which not a drop of rain falls, but it is used to signify a period of months or years during which little rain falls, and the country gets burnt up, grass and water disappear, crops become worthless and sheep and cattle die.

There are parts of the world in which you never hear of drought, but they tell you they have years of floods, and years of moderate rains, but nothing that can be called a drought, and yet we have in these variations of the rainfall exactly the same causes at work, which make in another place a serious drought; that is, a variation in the annual rainfall, and in the temperature and winds; but one place has a superabundance of rain and does not miss a small quantity, while the other has barely enough at any time, and a slight variation makes a drought. The interior of Australia and many other places are of this character, and our coast districts have a fairly abundant rainfall which modifies the drought conditions, and relatively we have little drought. In other words a drought is nothing if it has not a suitable local setting.

Drought is however not wholly made by a shortage of rainfall. Its most important factors are great heat and drying winds. As an illustration we may look to the year 1895; in the latter part of winter and in spring, there were many falls of rain, which would have made grass in ordinary seasons, but it had no sooner fallen than a dry north-west wind and burning sun dried it all up. This great and burning heat was a well known feature in historical droughts, and some authorities say that the fable of Phaeton driving the Chariot of the Sun so close to the earth that he set it on fire, is a poetical setting of an actual experience in Greece when the sun became so powerful that the heat was almost beyond endurance.

THE DIAGRAM.

Before 1895 all the diagrams I used had been made to show quantities of the various elements, as well as their relation in time with a view to seeing if there was any periodicity. Recently it occurred to me that it would be useful to have a diagram in which all the droughts *without regard to their intensity* should be placed in their *order of time;* not only was this desirable for seeing what the relation in time was, but it had become evident that it would be impossible to see the relation between our droughts and those in other countries, unless some such pictorial arrangement was

made. At the time it was not seen what a great saving of trouble and time this very simple device would ensure, but it is abundantly evident now, that this diagram has shortened by some years the attainment of the object I had in view.

As a preliminary to making the diagram, the particulars of the weather in this Colony from all sources, for every year of our history, were carefully examined, and the years simply classed *as good or bad*, that is, having sufficient or insufficient rainfall; a form was then prepared with a vertical space for each year, and across these a zero line was drawn to divide the good from the bad, and beginning with 1895 I filled in for that year, and below the line a convenient length of the column in *red ink*, the length was simply to catch the eye; then for 1894, a good year, I filled in with black ink above the line a space equal to the red in the vertical space for 1895. The two years were thus contrasted, simply as good and bad; the question of how good or how bad was purposely left out. The diagram was then completed, each year being treated in the same way back to 1788. It was at once apparent that the drought which has been lettered A for convenience was the most regular in its recurrence, and the most extensive in time, lasting as it does from three to seven years.

A vertical red line was then drawn through A between the first and second years, and it was found that the interval was regular and exactly nineteen years. In giving the date of any drought, the year after this line was used, being in all ordinary cases the middle year. Drought D was then examined and found to recur with nearly the same regularity, and a short vertical line was drawn under it to mark the point which has been taken as the centre, and this also recurs at intervals of nineteen years; there are three others, B, C, and E which also recur with an average interval of nineteen years, but they are not quite regular, may in fact differ from time to time a year or even two years, this uncertainty of time is indicated in the diagram by making the red space shorter.

The diagram takes in the whole period from the foundation of the colony to the present year, *i.e.*, one hundred and eight years, and it is certainly very noteworthy that the most pronounced droughts recur with such regularity, that is, at every nineteen years throughout the one hundred and eight years. It had been observed by me years ago that some of our great droughts had been world-wide, and when the diagram had got so far, it was decided to fill in the Indian droughts on a lower line, and see if they also coincided with Australian ones, and you see the result, viz., that in nearly all cases the great droughts in Australia had their counter parts in India.

The investigation had become interesting, and seemed to promise to show the exact year of the great drought in this country, of which there was abundant evidence when the colonists landed here, both in the fact that to the south of Sydney all the very large trees were dead and between them were growing young trees; and the story of the blacks who said that the river Hunter dried up, that all the great trees died and most of the blacks, that those who survived had obtained drinking water from the mountain springs. A similar story of the drying up of the Murrumbidgee and their sufferings was told by the blacks on the Murrumbidgee. I had long wanted to find out when this terrible drought in this Colony took place, and the Indian record showed that the A drought had been repeated in 1769-70 which probably fixes the date: for the middle of the eighteenth century was very dry generally all over the world.

A AND D DROUGHTS.

But, if we can carry the nineteen years period in this way back beyond our history, the idea immediately presents itself:—"Where are you going to draw the limit: is there any limit?" It was evidently not a question for argument, but for proof or disproof by figures. It was recollected at the moment, that history records a terrible drought and famine in India in 1022, and there was a similar one in South America about the same time.[1] Does it lie in

[1] Appendix No. 2.

the nineteen years' cycle was the question which naturally occurred to me? And it was seen that it did, for 19×43 takes us back from 1838 to 1021, that is, to a repetition of D drought, and on the spur of the moment the differences of opinion about the accuracy of B.C. dates was ignored and the figures were run out to see if the seven years famine in Egypt 1708 B.C. was in one of our nineteen years' cycles, and sure enough $19 \times 186 + 2$ takes us back to 1708 B.C., that is exactly the date of Pharaoh's famine; but Pharaoh's drought may for the present be discarded to appear again later; the fact that one famine in 1022, when dates may be taken to be reliable, should fall into the cycle was enough to suggest further investigation in reference to other recorded droughts, and all the records of droughts that had been collected in the last twenty years of general reading were tested to see if they fitted in. Tables were prepared showing every date on which A drought recurred back to A.D. 1, and the same for drought D. I am not going to weary you by going through the list,[1] but will give you the result. History says very little about droughts prior to A.D. 900, between that date and this, A drought has, on the assumption, occurred at every nineteen years. In this interval of nine hundred and ninety-six years there have been fifty-two repetitions of A drought, and the question is, what has history to say about its droughts. Well, it shows that these droughts have been repeated at various places on the earth on forty-four of the fifty-two dates; of these eight missing droughts, no less than six of them occurred between 1100 and 900 A.D., an interval when history was less complete on these matters. So far as I have gone history furnishes us with seventy-eight droughts in different countries, all of which fit into the series which we have named A. During the same period, D recurred fifty-one times, and history records droughts, numbering eighty-nine, on thirty-six of these periods. Taking then the droughts history has recorded between A.D. 900 and 1896 we have seventy-eight A, and eighty-nine D, a total of one hundred and sixty-seven, out of two hundred

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[1] Appendix No. 1.

and eight on record ; but this is not all, for the drought E which is irregular in Australia, seems to be more definite and important in the northern hemisphere, and twenty-six more out of the two hundred and eight fit into E series making up the number to one hundred and ninety-three out of the total of two hundred and eight.

In estimating the importance of these figures, it must be remembered that North and South America, Russia, China, Persia, Turkey, Austria and Australia, before 1788, all subject to frequent drought, yet did not furnish to the numbers quoted more droughts than you could count on your fingers, and it may be fairly assumed that if we had these records, and especially if history had made a point of recording droughts, we should have had drought recorded on every recurrence of the A and D nineteen years' cycle, but I think the evidence, that history furnishes one hundred and ninety-three recorded droughts every one of which fits into the cycle, justifies us in assuming that the nineteen years' cycle has been running for at least one thousand years, and may be trusted to continue and justify forecasts based upon it for some time to come.

Having got so much from a study of A and D in the Christian era, it seemed desirable to see if there were any recorded in B.C. times and the following were found : one drought in Abraham's time given as 1920 B.C., does not fit into the cycle.

(1) Gen. xxvi. 1, in the time of Isaac, 1,804 B.C., 3,632 years before A ; this interval is a multiple of nineteen years, *i.e.*, $19 \times 181 + 3$.

(2) Gen. xli. 54, Pharaoh's (seven years), 3,536 years before A $= 19 \times 186 + 2$.

(3) II. Sam. xxi. 1, David's time, 2,849 years before A $= 19 \times 150 + 1$.

(4) I. Kings xvii. 1, Elijah's drought, 2,736 years before A $= 19 \times 144$.

(5) II. Kings viii. 1, Elisha's drought, 2,717 years before A $= 19 \times 143$.

You will observe that the interval between (4) and (5) is nineteen years, between (3) and (4) is six times nineteen years, between (2) and (3) thirty-six times nineteen years.

For the convenience of having all the B.C. droughts together, we will bring forward from "Red Rains" the droughts which are therein found, and two from Roman and one Grecian history. First then the Roman

(6) 493 B.C., drought at Rome, 2321 years before 1828 is in A series, interval is $19 \times 122 + 3$.

(7) 436 B.C., drought at Rome, thousands of persons threw themselves into the Tiber, to avoid death by starvation; 2,264 years before 1828 is in A series, interval $19 \times 119 + 3$.

(8) 138 B.C., a drought over the world 1,976 years before 1838, is therefore in D series, interval 19×104. It is worth mentioning that in India from 503 B.C. to 443 B.C. there was great drought and pestilence, and these dates are in the D series.

(9) 503 B.C., great drought in India 2,341 years before 1838, interval $19 \times 123 + 4$. (D)

(10) 443 B.C., end of great drought, 2,281 years before 1838, interval $19 \times 120 + 1$. (D)

RED RAINS.

(11) 738 B.C., red rain in Rome 2,566 years before 1828, interval $19 \times 135 + 1$. (A)

(12) 652 B.C., red rain fell in Avis, 2,490 years, interval $19 \times 131 + 1$. (D)

(13) 650 B.C.
(14) 648 B.C. } parts of same drought as No. 12. (D)

(15) 626 B.C., red rain at Ceres 2,454 years before 1828, interval $19 \times 129 + 3$. (A) This rain was at the end of the drought.

(16) 587 B.C., rained blood in the campagna 2,415 years before 1828, interval $19 \times 127 + 2$. (A)

(17) 585 B.C., rained blood on one day in Rome 2,413 years before 1828, interval 19×127. (A) The beginning of the same drought as No. 16.

(18) 572 B.C., rained blood on the squares of Vulcan and Concordia for two days, 2,414 years before 1842, interval $19 \times 127 + 1$. (E)

(19) 570 B.C. The beginning of same drought as No. 18.

(20) 538 B.C., blood rain in Rome 2,376 years before 1838, interval $19 \times 25 + 1$.

We have in this list (omitting 13, 14, and 17) seventeen B.C. droughts, all of which with one exception, fit into our nineteen years' cycle. If these dates are examined apart from their connection with Australian droughts, we find that the intervals between them, are multiples of nineteen years, which shows, that droughts recurred then as now, in cycles of nineteen years, and this is very strong evidence in favour of our theory. The more so when it is remembered that all the B.C. droughts I have been able to find, except one, do fit in ; they are not a series selected out of many, for the purpose of supporting the nineteen years period, but they are all that can be found. Again taking the dates given in history, the intervals between these B.C. droughts and ours in Australia are multiples as we have just seen of nineteen years.

If it be objected that chronologists have grave doubts as to the accuracy of B.C. dates, I reply that whether they be correct or not, it is quite certain that historians did not purposely arrange the dates in order to make them fit into a cycle, running amongst these droughts, that was unknown to them, or to make them fit into the Australian cycle, which had not even been discovered.

These drought dates are well marked points in ancient history, and the fact that they fit into a cycle, supported by all the known droughts of the last thousand years of the world's history, is in strong confirmation of the accuracy of these B.C. dates.

The figures show that Elijah's prediction was a repetition of Pharaoh's drought 42×19 years after it ; also Elisha's prediction was nineteen years after Elijah's, and it is noteworthy that the drought in David's time, although it does not appear to have

been predicted, was 19×36 after Pharaoh's. This seems to me to be very strong evidence in favour of the view that the Egyptians knew of the nineteen years' cycle, and that the Jews brought the knowledge away with them.

Those learned in Assyrian antiquities tell us that the book containing "the Observations of Bel," the oldest astronomical book of that part of the world, was ordered to be kept by the king of Saros 3,800 years B.C.; that book shows that they kept a record of astronomical and all other events, that they had discovered the nineteen years' cycle of eclipses, and we are told that they believed that one event caused another, and all astronomical and meteorological observations were thus bound up together. Under such conditions I do not think it would be possible for them to avoid finding in the droughts a similar period to that in the eclipses, *i.e.*, nineteen years, but even if they did it would have been impossible for those who kept the Nilometer in Egypt to avoid finding it in the variations of the heights of the Nile floods which were of such vital importance and so carefully recorded.

Having got so far, I looked for any droughts mentioned in Roman history, to see if they would coincide like the others with the nineteen years' cycle, and found two, one in 493 and the other in 436 B.C., in both cases these are repetitions of the A drought, but the historian has quoted the end of the drought for they are three years after my date, which is the second year of a drought that lasts from four to seven years. History tells us that in 138 B.C. there was a drought over the whole world, and the heat is said to have been excessively great: this intense heat, is one of the most marked feature of a D drought to-day; witness the excessive temperatures of January last, and the record temperature of Australia 127° at Bourke, was nineteen years before in 1877; while intense heat was a feature of January 1858, scorching heat of January 1839, and intense heat February 1820; such is the D drought series in Australia.

We thus see that five out of six Scripture droughts fit into the nineteen years cycle, two from Roman history, and one from

Grecian, and nine from red rain, in all seventeen B.C. droughts, agree in supporting the cycle.

The evidence of these droughts is very strong because it is so nearly unanimous; and, as we shall see presently, it receives support from an unexpected quarter. In passing, I may mention that the interval between the dates four hundred and ninety-three and four hundred and thirty-six is fifty-seven years, or three times nineteen.

RED RAIN.

Since I have been working at this subject there have been a number of red rain storms noted in this Colony, and the latest on April 10, suggested to me this line of investigation. Red dust is obviously a proof of drought somewhere, otherwise the dust could not rise, and since these proofs of drought are entirely apart from the others, and recorded not as droughts but as *prodigies*, which in days gone by created no little alarm; it will be worth while to see how far they support or contradict the nineteen years cycle. The result of this resolution came as a surprise to me because it was so unexpected, I had no idea there were so many records of red rains, or that they so strongly supported the nineteen years' cycle.

There are altogether sixty-nine recorded instances of the fall of red rain, of these I have recorded six for New South Wales. The first historic red rain was fourteen years after the foundation of the city of Rome, that is in B.C. 738, and there are nine others B.C., all of which fit into the nineteen years' cycle; between 538 B.C. to 582 A.D. I can find no record of red rain, but from 582 to 1896 there are fifty-nine recorded falls of red rain, and all of them fit into the nineteen years' cycle. We have here then nine B.C. droughts which go with the eight mentioned before to make seventeen B.C. droughts in support of the cycle, the remainder, fifty-nine, are included with a few exceptions in appendices Nos. 1 and 2.

HURRICANES COME IN DROUGHTS.

I should like it to be clearly understood that I do not mean ordinary hurricanes which are as much parts of ordinary weather conditions in some parts of the world, as our southerly winds are here. What I mean are *extraordinary hurricanes*, those that came at long intervals to terrify mankind by their power for destruction. These are connected with droughts, and therefore should be discussed here. I had years since observed that the connection between the two was obvious enough sometimes, and during the past year I was reminded of it very often by the frequent reports of heavy gales met with by ships coming to this port, indicating great atmospheric energy. Then on March 24, 1895 occurred the worst gale of the Nineteenth Century in England, which did more damage there than any other gale since 1703. Then on January 3, 1896, came the hurricane over the Tongan group of islands, and not one of the vessels in the harbour rode out the storm; every one of them was wrecked before morning, and the wind was of such exceptional violence that after it was over, the islands looked as if they had been bombarded.

And as I write, May 28, we have the report of a terrible cyclone in America, by which three of the States, Missouri, Illinois and Indiana were damaged, the city of St. Louis was wrecked, and 1,500 people killed by falling buildings, and damage to property caused to the extent, as estimated, of twenty millions of dollars; this is another fragment of the present D drought.

Then I turned to storms on this coast, some of which were of terrible violence.

DANDENONG GALE IN DROUGHT D.

And as I looked, memory ran over the storms of the past and picked out the most terrible gale of which we have any record in Australia, viz., the Dandenong storm, on 10th of September, 1876, just nineteen years before 1895, a storm in which a very fine steamer the "Dandenong," going to Melbourne foundered, and all hands were lost. In parts of this storm gusts of wind reached one hundred and forty and one hundred fifty-three miles per hour.

CAWARRA IN DROUGHT A.

Then the "Cawarra" Gale, a most furious easterly storm in which this fine steamer was wrecked at the entrance to Newcastle, N. S. Wales, on July 12, 1866, in the great drought period which we have called A.

DUNBAR IN DROUGHT D.

And on going back another step, I remembered the loss of the "Dunbar" at Sydney heads, in a tremendous easterly gale, on 20th August, 1857, just nineteen years before the "Dandenong" was wrecked. It is not my purpose to describe these wrecks, I only recall them as the most memorable that our short history affords, and the fact that they all occurred in our great drought periods, set me searching history to see if great storms and droughts had any connection.

That there is such a connection seems, *a priori*, extremely probable, because the great heat that accompanies a drought furnishes that additional impulse to the circulation of the wind which is necessary to urge it into violent storms; for a comparatively small additional impulse over the large area of the equatorial regions, would supply the energy necessary for these very violent local storms. The heat is a matter of common observation, and the hurricane at such periods is found by the careful observer to be something unusual, and possessed of a restless energy in drought times. It was soon found that the conditions observed in a few cases of my own experience were amply confirmed by a search which was carried back for six hundred years. Sixty-two hurricanes were found, the greater majority being between 1700 and the present day, and only exceptionally violent hurricanes were selected, such as are quite distinct from the ordinary hurricane or storm, and when these came to be compared with the drought periods it was found that every one had occurred in a drought year; and further, that those of the greatest violence belong to the D drought, which is remarkable for its great heat and the energy of its winds.

GREAT FROSTS.

Another interesting series of phenomena connected with droughts I find in the great frosts of Europe—the absence of cloud in these seasons, due to the dryness of the air, permits of extreme radiation at night, and hence great cold is frequent in drought winters, as heat of unusual severity is experienced in the summers, and it is another proof of the hold these drought periods have on the weather. But let us turn to the lists of the great frosts of Europe, collected by the celebrated astronomer Arago—they were not collected for the purpose I am going to use them, but he selected all of them from ten centuries of European records—as there are only sixteen in a thousand years, it is safe to assume they were of exceptional severity; and they are so beyond question. Our present purpose with them, however, is to see whether they support in any way our theory.—Eleven of them fall directly into the A drought, three of them fall directly into the D Drought, and three into one of the minor droughts lettered E.

306, the Rhone was frozen over, (end of a long A drought)

833, the Po was frozen over from Cremona to the sea (D)

1234, loaded waggons crossed the Adriatic on ice in front of Venice (E)

1305, all the rivers of France were frozen (D)

1324, people travelled from Denmark to Lubeck and Dantzic on the ice (D)

1334, all the rivers in the South-east of France and all those of Northern and Central Italy were frozen and the frost lasted in Paris two months and twenty days (A)

1468, it was necessary to break up the wine in Flanders with hatchets in order to serve it out to the soldiers, owing to the intense cold (A)

1544, the wine in France frozen; had to be broken up before issue to the soldiers (A)

1594, the Mediterranean was frozen over from Marseilles to Venice (E)

1657, the Seine was completely frozen over (A)

1709, the Adriatic and the Mediterranean were frozen over (E)
1717, shops were established on the Thames (A)
1742, the Seine was entirely frozen over (A)
1744, Seine entirely frozen over (A)
1766, Seine entirely frozen over (A)
1767, Seine entirely frozen over (A)
1895, the Thames frozen over (A)
(A) eleven, (D) three, (E) three.

THE DEAD SEA.

One finds it commonly stated in books that the Dead Sea is gradually drying up and perhaps it is, but there are very considerable alterations in the level of it; for instance Lieut. Conder, when surveying Palestine, June 1872 to June 1875, found it did change its level considerably, and at page 220 of "Tent Work in Palestine," he states, "Sheikh Jemil, the most intelligent Arab near Jericho, told me that in his father's time the sea did not generally reach further inland than the Rujum el Bahr. Whereas now the connecting causeway is always under water. This represents a rise of some ten feet in the water level. In fact according to this statement, the sea had now (1873 or 1874) more water in it than it used to have half a century ago."

From this it would seem more than probable that the Dead Sea followed the same course as Lake George, where the water gradually disappeared after 1826, was all gone in 1838, and remained only a shadow of its true self until 1852, when it began to fill up, and in 1874 attained its maximum flood. Lake Titicaca followed much the same order. So that we have here lakes in Asia, South America and Australia, drying up in the great droughts of 1828 and 1838 and during the small rainfall of the whole period 1825 to 1851, and filling up after that year.

EGYPT.

Mr. Anderson, Principal Librarian of the Public Library, has given me very cordial assistance in my search for particulars of the climate of Egypt, and, as a consequence, I found in the works

he brought under my notice records of droughts, or, as it is there termed, "low Nile" on nineteen years. Five belong to A drought in our cycle, and twelve belong to D: that is seventeen out of nineteen correspond with dry periods in New South Wales, and the other two correspond with one of our minor droughts; and I see that, in Egypt as in England, their weather change comes about a year before ours in Australia.

BREAKS IN DROUGHTS.

It is not my purpose to night to go into the details of the life of a drought; I am writing to try and prove to you that there is a cycle which rightly understood will be of the utmost value to this Colony. At another time I have to go into what might be called the personal history of a drought; but there is one feature of their history that bears so strangely upon their periodicity, that I cannot defer it, although this matter more correctly belongs to their personal history: I refer to their sudden interruption by violent rains extending over small areas; you will see in what follows that this is a feature that comes in a certain month in each series A and D, and for the moment seems to break up the drought, but the drought nevertheless returns to omplete its full course.

This break is a well-marked feature of droughts, and one that is very apt to, and very frequently does, mislead those who do not study the drought as a whole. A very good illustration of this has been before us quite recently in this D series. A very heavy rain storm came on in February, 1896, in the north-western districts, as much as ten inches falling in a single night in some places. But when one comes to look carefully at the character of the rain, we find that the most marked feature of it is that it is not general, but made up of a series of violent local storms, each confined to small areas, but widely separated from one another, and connected only by comparatively light rains; and, further, that these storm-bursts, as they are sometimes called, discharge the rain so rapidly that it has not time to sink in, but runs away to the nearest water-course, and therefore, fails

to do that amount of good which we should expect from the quantity measured.

Unfortunately, one cannot, as a rule, learn the area of these storms, but many circumstances, such as the absence of the same heavy rain at neighbouring stations indicate the fact, and sometimes they cover only a small part of one station. I may illustrate what I mean, both as to the area covered by the rain and the immense quantity that comes down, by the experience of a friend, Mr. L. S. Donaldson, in 1869, on page 87.

One of the most remarkable and best known rain storms inland occurred in the end of January, 1885, when we were right in the middle of A drought. The storm came in at the north-west corner of the colony, and travelled thence in an east south-east direction, straight across New South Wales to the sea, depositing from six to eleven inches in a day and a half as it passed on. From the central line of heaviest rain, which passed over Wilcannia, the quantity of rain fell off rapidly, so that at Bourke the river rose only four feet, while at Wilcannia it rose twenty-eight feet ; but the rain messenger having made his way over the colony, drought again took possession, and it did not break until the middle of the year 1886.

Just nineteen years before this storm of 1885, a very similar storm passed over Bourke in January, 1866 (again in A drought); very heavy rain fell, but the river did not rise much, although the rain lasted two days, showing that the rain area was small. Nineteen years before this there is no record (*i.e.*, in 1847) of what took place in the then unoccupied Darling Country, but it is worth mentioning as evidence so far, that there was such a storm in the West, that an exactly similar storm passed over the Paterson River on January 17th, 1847, just as the one in 1885 passed over Lake George and deposited eight inches of rain there; at the Paterson, it rained so heavily during the day that the river rose higher than it had been for some years before.

I have already alluded to the recent (February 1896) rain storm over Bourke and the Bogan country and its remarkably

patchy character. It is worth while adding that it is evident from the few records available (only two stations west of the Darling) that a similar storm occurred in February 1877; for in February "Momba" Station had a storm and four inches of rain, and "Yancania," seven and a half inches in the same month, nineteen years before that of the present year 1896. In 1858 no one on the Darling River thought of rainfall records, and the few notes left by those who were taking up the country there do not help us at all; but Dr. Glennie's record at the Paterson again comes to our aid and tells us that on February 2nd, 1858 a most tremendous rain and hail storm with thunder and lightning passed over the Paterson. I mention these peculiar rain storms just to show how they repeat themselves as notable parts of the weather at intervals of nineteen years, and it is to be noted that in A droughts the storm came in January, and D series in February.

But it is not alone in these storm rains that these features of drought are repeated, it shows in many ways and not least in temperature; for instance, we all remember the intense heat of January 1896, when one hundred and sixty deaths were attributed to the great power of the sun in the Bourke district, we find intense heat occurred at nineteen years' intervals before that in January 1877, 1858, 1839, and 1820; in 1839 it was so severe that the vines, grapes, and leaves were burnt up; the latter crumbling to the touch as if they had been baked.

I will add just one more because it is in a short sharp drought which only lasted a year and finds its type in 1888. In that year on February 8th, a very heavy rain storm accompanied by thunder and lightning came into the Colony from the north, and reached Moree at 7·45 p.m. on that day; so heavy was it that the whole of the surrounding country was flooded, and the local rain caused a rise in the river of ten feet. It spread over the Namoi, Macquarie and Bogan Rivers, but did not go south of Dubbo. Just nineteen years before in February 1869, Mr. L. S. Donaldson, P.M., who was then living on the Bogan, tells me that the February 1896 storm reminded him of a heavy flood rain in the former year.

It was, he says, not so extensive as the recent ones, but on that occasion the rain fell at Moonagie, near Cannonbar ; the River Bogan was dry throughout its course, except a waterhole at long intervals. The rain fell over only about a mile and a half of the river, and for only about one hour, but such a quantity of rain fell (we had no rain gauges then) that the river ran for seventy miles, into the long waterhole at Gongolgon. The rain was accompanied by large hailstones, which went through verandahs, and killed emus and kangaroos, and stripped all the leaves off the trees till they looked like English trees in winter."

GOOD SEASONS.

Looking at the diagram, we find that there are as many good seasons as bad ones. Some of these recur with great regularity, for instance, the two years immediately before the commencement of A drought, and likewise the two years immediately following D drought. Then there are three good years together that come as a rule four years after the centre of A drought; their regularity is made uncertain by the irregularity of the end of A drought.

Before A.	Following A.	Following D.
1787-8	1794-5-6	1802-3
1806-7	1813-4-5	1821-2
1825-6	1832-3-4	1840-1
1844-5	1851-2-3	1859-0
1863-4	1870-1-2	1878-9
1882-3	1889-90-1	1897-8

In 1893 we had the lowest grass temperature on record, and a very wet year on the coast although inland it was dry. The series runs—on the coast—

1893, heavy floods, lowest grass temperature on record.
1874, many heavy floods.
1855, no record of this year.
1836, abundance of rain, snow fell in Sydney.
1817, high floods on the coast and inland.
1798, " wet, and in July uncommon cold."

It thus appears that good years precede and follow great droughts in the cycle, and while D carrys its heat and its winds with it. The 1893 series carries its floods and its low temperatures.

I have thus endeavoured to put before you some of the reasons which have convinced me that there is a cycle in weather, but the necessity for brevity in order to keep the proof within the limits of one address, has rendered it necessary to express in a few sentences the results of many separate investigations, and the evidence does not seem so strong when thus condensed, as it does when a number of facts one by one are brought to light from diverse sources, all of which individually support the proposition. I can assure you that the evidence was far more convincing when taken in detail, but want of time to get these details into one address, make this course impossible. Enough appears to have been said to prove that the cycle does exist, and to show you the very great importance of this re-discovery of a law of climate, which, there are many reasons to think was well-known to the Jews, the Egyptians, and other ancient peoples; they at least knew how to forecast droughts successfully, and in Egypt, like sensible people made provision for them.

We have in the diagram, the weather of one hundred and eight years of New South Wales Climate, arranged in order of date (the intensity being for the time overlooked); the black spaces above the line represent the good years, while the red spaces below the line represent the bad years. It is evident upon inspection that certain features of it recur every nineteen years; we have seen that the droughts of history, the great and conspicuous droughts I mean, all drop into this same cycle: both those that happened before the birth of Christ and those that have occurred in our era.

We have seen that great hurricanes, the great frosts of history, all the red rains, and all the droughts that history records, with a very few exceptions, are likewise included in this cycle, and that the level of great lakes in Palestine, South America, and New South Wales, are subject to the same mysterious influence that

controls our weather, and a search for the cause has not been forgotten.

THE CAUSE OF DROUGHTS.

As my investigation proceeded, the weight of evidence gradually converged upon the moon as the exciting cause. I have never had any sympathy with the theory of lunar influence upon weather, and received, rather against my will, the evidence that presented itself, but the logic of facts left no alternative, but to accept the moon as prime motor. There has not been time to complete this investigation, and when finished it must form another paper. Meantime I may say that so far the comparison of the moon's positions in relation to the sun and earth and droughts shews that when the eclipses congregate about the equinoxes, that is in March and September, they do so in the years which give us great droughts, the As and Ds of our series. Further that when the eclipses accumulate in February and March, that is at the vernal equinox, and the month before it, and September the autumnal equinox, and the month before it, August, we have the more intense and relatively shorter D droughts, with heat, gales and hurricanes; on the other hand, when they accumulate about March and April, that is the month of equinox, and the one following, and about September the month of equinox, and October following it, we have A droughts, that are less severe, but much longer than the D droughts. But I must stop for the present.

I have already pointed out the use of the diagram, and a few words in reference to it will close what I have to say to-night. I have spoken chiefly of droughts, but so far as our own history is concerned it would have served the purpose just as well if I had taken up the periodicity of wet years, but outside Australia it would have been very difficult to get the necessary data, for history has much more to say about the horrors of drought than the abundance of wet seasons. The diagram presents one fact that will be of interest to many in this droughty time, it is the forecast of good seasons in 1897 and 1898.

SUN SPOTS.

For convenient reference, I have put on the diagram the maxima and minima of the sun spots. You will see at once that the recurrence of the period is very far from being the regular eleven years cycle which many persons suppose it to be, and it is equally far from being in accordance with the cycle that I have endeavoured to demonstrate to-night.

APPENDIX I.

List of Droughts of the A Series.

Year.

1885 1886, great drought in Texas; grass completely destroyed, calves nearly all dead; 180,000 head of cattle on the move; estimated loss so far (Sept. 1886) $3,000,000. (*Evening News.*)

1886, drought in Ireland for past three years. (*Mr. Pollock.*)

The *Scottish Agricultural Gazette*, March 1886, says, the losses in stock in the Argentine Republic have been exceptionally heavy, no less than 70% of the cattle and sheep on some estancieros having perished; the estimated loss in sheep in the Republic is 5,000,000 since this time last year.

1885 France. Rainfall has been below the average in almost every month since January 1883. (*Journal of Science*, Feb. 1885, p. 116).

1885 This drought in New South Wales was considered to be the worst since 1837-8. The estimated loss of sheep alone was nine millions. The Darling at Bourke was below summer level seventeen months out of the two years 1884-5, and during the other months never rose more than ten feet. Even on the coast, the Paterson River had become a chain of water holes in February 1884.

1885 Red rain fell in December 1883; in February and again in March, 1884; in August 1885. A proof of the intensity of this drought.

1866 Great drought in Bengal and Orissa; one and a half millions of people died from starvation. (*Journal of Science.*)

Year. List of Droughts of the A Series.

In Mauritius from 1861 to 1868 the rainfall was less than during any similar period, so far as can be ascertained since the discovery of the island. (*Physical Geography*, p. 171, *Laughton*)

Bousingalt wrote, "The table lands of New Grenada at an elevation of from 6,500 to 9,000 feet. The village of Dubati is situated near two lakes, which were united in 1807; the inhabitants had witnessed the gradual subsidence of the waters, in so much that lands which in 1837 were under water are now 1867, under cultivation. (*Smithson. Rep.* 1869.)

1864 Drought in Russia.

1846-7 Great Famine known as Potato Famine in Ireland.

1847, great drought in South Africa. (*Livingstone* pp. 17-18, *South Africa.*)

Red rain 1846, and again 1847.

Very severe drought in New South Wales.

Great drought in England 1845 and 1846.

1828 1827, great drought in England which lasted two years.

1826, great heat and drought in Europe. (*Herschel, Metr.*)

1826, the late drought in Russia caused a rise in the price of flax. (*Climate N.S.W.*, p. 95.)

1827, "on the Pampas and the Chaco of La Plata these droughts produce the most remarkable results with regard to the distribution of animals. In the drought of 1827-8-9 the drought still spoken of as "Il gran seco," the destruction of life was enormous, not only amongst the cattle, but also amongst wild beasts, of which last, indeed some species were altogether annihilated." (*Laughton, Phys. Geography*, p. 154)

1828 "During this time (*i.e.*, 1827-28-29) so little rain fell that vegetation even to thistles failed. The brooks were dried up and the whole country (the Pampas in South America) assumed the appearance of a dusty road. This was especially the case in the northern part of Buenos Ayres, and the

Year. List of Droughts of the A Series.

southern part of "Santa Fé," very great numbers of birds, wild animals, cattle and horses perished from want of food and water. The lowest estimation of the loss of cattle in the province of Buenos Ayres alone, was taken at one million head." (*Laughton, Phys. Geography*, p. 33.)

1809 The intense drought of 1811 in Europe was accompanied by hurricanes and earthquakes. (*Eng. Mechanic*, Vol. XXXIX., 1884, p. 507, quoting an Italian savant.)

1812, great drought in Venezuela, not a drop of rain had fallen at Caracas or within two hundred and fifty miles of it for five months before this. (*Boschovish on Earthquakes*, p, 131.)

1790 A great drought in 1790-2 in "Baroda," India and some adjoining districts. (*Ency. Brit. et Journal of Science*, 1878.)

1771 "During 1769-70 the great drought in India killed three millions of people. In 1770 the heat in India was so terrible that many persons died of asphyxia (? heat apoplexy) others saved themselves by going into caves and pits." (*Eng. Mech. Jour. Sci.*) Mulhall, *Dic. Dates*, says "this was considered the worst drought of modern times."

1752 Drought in India 1745 to 1752, in 1753 many died from excessive heat. Temperature 100° to 104°. (*Walford.*)

1733 Great drought in the north-west provinces of India this year.

1714 Exceedingly hot and dry in England 1716. (*Walford.*)

1695 1693, an awful famine in France. 1693-4, hot drought in Italy.

1676 1678, hot and dry throughout this year in England. (*Walford, Journal of the Statistical Society.*)

1657 Scorchingly hot and dry in England. 1657-8, drought and famine in Rome.

1638 1637-8, hot and dry in England. Red rain 1638 and 1640.

1619 1616, exceedingly hot and dry in England. (*Walford.*)

Year. List of Droughts of the A Series.

1600 1601 to 1603, great drought and famine in Ireland. Same in England. Great drought in Russia.

1581 Drought in Persia. Red rain 1580. 1583, excessively hot and dry in England.

1562 1563, drought and pestilence in India, carried off 20,000 people.

1543 A wonderful drought in England. 1540 to 1543, three years drought in India.

1524 Severe drought in England.

1505 1503, great drought in England.

1486 Great drought in England.

1467 No record.

1448 1447, great drought in Ireland and England with heat.

1429 Drought in Scotland.

1410 Great drought in the delta of the Ganges India 1412-13.

1391 Great drought for two years in England.

1372 No record.

1353 1352-3, great drought and famine in England, France, and Italy.

1334 1332, drought in Ireland.

1315 1316, drought in England, grain was so scarce that there there was none to make beer.

1296 1294, universal drought in England.

1277 1280, drought in England for three years. 1277, all the largest rivers in Europe shrank to the tiniest rivulets owing to drought. (*Eng. Mech.* Vol. xxxix., p. 506).

1258 1259, droughts in England. 1260, the Rhine, the Seine, the Po, and the Tiber shrank to the tiniest rivulets owing to drought. (Italian Essay—*Eng. Mech.* Vol. xxxix., p. 506.)

1239 Great famine in England, people eat their children.

1220 No record.

1201 Drought in Egypt. (*Modern Egypt*, p. 115)

1182 Red dust 1181. Red dust 1184.

1163 Red dust; drought and famine all over the world.

Year. List of Droughts of the A Series.

1144 Drought during all harvest and long after in England.

1125 1123-4, terrible drought in France and Germany. (*Walford*)

1106 Drought in England. (*Walford.*)

1087 No record.

1068 1064, drought in Egypt for seven years. (*Modern Egypt.*)

This is probably E united to A.

1049, 1030 No record.

1011 1012, drought in England and Germany.

992 993, vegetation was burnt up by the sun as if by fire. (*Eng. Mech.*, Vol. XXXIX., p. 506.

973 975, the great famine of Paris.

954, 935, 916 No record.

897 The water supply of Italy, France, and Germany was entirely dried up by drought; vast numbers of peasants were struck down by the intense heat of the sun. (*Eng. Mech.*, Vol. XXXIX., p. 506.

764 762, long and terrible heat, Britain; 767, great drought in Asia. A and B united.

645 Great drought in England.

479 480, drought in Scotland.

460 No record.

441 439, drought in Britain.

APPENDIX II.

Year. List of Droughts of the D Series.

1895 Drought in New South Wales.

Red rain, April 10, 1896. Drought in England.

1894, a terrible drought in Antiqua, West Indies.

1896, farmers in Spain are being ruined by protracted drought. (*Sydney Morning Herald.*)

1895, drought in Norfolk Island.

1896, excessively high temperatures in India.

Year. List of Droughts of the D Series.

1895-6, drought in China about Honkong. (*S.M. Herald.*)

1896, Jan. 8, South Africa, no harvest to speak of for three years, no grass, no water, and the rainy season over, so that there is no hope of rain until April or May.

1876 Drought in West Indies, Guinea, Venezuela, Columbia, and Brazil.

1878, United States, excessively high temperatures 90° to 110°; in Canada 90° to 103°, at Milwaukie 103 cases of sun stroke, at St. Louis 1,500 cases of sun stroke.

Drought in India 1875-6-7, half a million of people died, Madras, Mysore, and parts of Bombay. "Madras, Oct. 17, 1876, the state of Kurnool, Bellary, Cuddapah, North Arcot, and Chingleput districts, and also Mysore, is alarming, owing to the drought. In the Bombay Presidency six millions of people are threatened with famine by the failure of the monsoon rain. Relief cost £9,000,000. (*Jour. Sci.*)

1878, great drought in Barbary.

1876, severe drought in Spain.

1876, drought in Samara, Eastern Russia.

1877, June 18, "China," "Chihle," and "Shantug" districts containing many millions of inhabitants, the harvest had failed for two years running, neither grain nor food were to be had at any price; the whole country seems to have been scorched by a burning wind; people eat every bit of grass, or bark or leaves off trees that they could find, and to avoid death by starvation, committed suicide. In Chefoo it is stated on good authority, that human flesh was actually offered for sale in the shops until prohibited by the mandarins.

1877, in Southern California there was a total failure of crops, and millions of sheep died.

1876 "Cape Colony, Australia, South Sea Islands, and it would appear almost every known portion of the Southern Hemisphere have been suffering from severe and protracted drought. In Australia shade temperatures of 124° and 127°

Year. List of Droughts of the D Series.

are reported ; sheep cattle and horses and wild animals of these regions are dying off in thousands." The heat in the east of Cape Colony during January 1878 is described as the most disastrous ever known in that region.—*Nature*, Vol. XVII., p. 436.

(Goldsbrough & Co., estimated that in Australia the loss of sheep alone at nine millions in the 1877-8 drought; to this has to be added the losses of wool, cattle, horses and farm produce ; Sir James M'Cullock, estimated the loss on the sale of wool alone at £2,000,000).

1876 In Cape Colony *(Nature, ibid.)* complete ruin has overtaken a large number of the settlers, many of the homes of hitherto well to do colonists have been broken up, and the several members obliged to go into menial service in exchange for the barest necessaries of life.

In the South Seas we find the same dire effects of the 1876-77 drought ; it began in 1876 and lasted all 1877, many of the natives died of starvation, so severe was the drought. The Rev. S. J. Whitmee writes, "we have had the greatest drought I have ever known." In Tanna, New Hebrides, the crops completely failed and many of the people died of starvation.

In the Island of Ascension there was no rain for fourteen months before August 1877, and the supply of fresh water for each person had to be reduced to one gallon per day.

In Egypt in 1877 they had the lowest Nile on record, a proof of the severity of the drought at its source.

1857 Drought in India 1856-7.

Admiral Fitzroy states that in 1858 and 1859 drought prevailed in Africa, America, West Indies and Australia, 1857-8 drought in England did not break up until Sept. 1859, but in South Africa and Australia it broke up before that.

1838 1837-8-9, severe drought in parts of the north-west provinces of India ; 800,000 people died.

Year. List of Droughts of the D Series.

January 1839, weather scorching hot in New South Wales, River Cowpastures New South Wales dried up, not as much rain the past two years as would suffice for two months. Murrumbidgee also dried up. The drought in Australia during 1837-8-9 was one of the worst ever known here. Red rain in 1839.

1819 Great drought in Germany 1821, all vegetation parched up and even the rivers dried up.

England 1819, very hot and dry, no rain fell for 74 days.

New South Wales suffered considerably from drought 1818-19. 1821, red rain fell.

1800 Drought in New South Walea.

1781 1781-82, drought and famine in Madras and Carnatic in 1872-3 drought in "Sind," no rainfall for two years.

1783-4, drought in Punjaub during these years.

1779, excessive heat at Bologna, many died of sunstroke, and many others to escape the heat, took refuge in pits and caves underground. (*Eng. Mech.*, Vol. xxxix., p. 506.)

1762 1763, red rain.

1743 Red rain 1744.

1724 No record.

1705 1704, the hottest and driest summer in England, continued to August 1705.

1705, the temperature rose so high in Europe that it resembled that of a glass house furnace, and butcher's meat was cooked in the sun, and from midday to 4 p.m. no one ventured out of doors. (*Eng. Mech.*, Vol. xxxix., p. 506.)

1686 Red rain fell in 1689; 1684 was a very dry year in England.

1686, great drought in Italy.

1667 1666, hot and dry easterly winds in England; 1669, the whole year was hot and dry in England. Red rain fell in this year, 1669.

1648 No record.

Year. List of Droughts of the D Series.

1629 1630, drought in England; 1631, drought and famine in India and throughout Asia.

1610 Excessive heat and drought in England; red rain fell.

1591 1590-92, extreme heat in England with plagues of insects.

1572 Red rain fell 1571.

1553 1651 to 1654, in England they had scorching hot and dry summers.

1534 No record.

1515 1516-17, hot and dry in England.

1496 1498, very great drought in England.

1477 Great heat and drought in England.

1458 No record.

1439 1437, wheat sold in England for six times its normal price.

1420 Red rain, March 1822.

1401
1382 } No record.

1363 1361, very grevious drought in England.

1344 1344-5, all Hindustan suffered from drought and famine.

1325 No record.

1306 1303-4-5, protracted drought in Europe, in so much that the largest rivers of Europe, the Rhine, the Seine, the Po, and the Tiber, all shrank to the tiniest streamlets. (*Eng. Mech.*, Vol. XXXIX., p. 506.)

1287 1285, great and sudden darkness, then such drought and and heat as killed most grain in England.

1288, heat and drought so intense that it killed many persons.

1154 1152, very dry and cold, followed after harvest by greatest heat and drought.

1135 1135 and 1137, great drought in France and England.

In 1132 the earth was so burnt up by the intense solar heat that that great fissures appeared in it miles long. (*Eng. Mech.*, XXXIX.

List of Droughts of the D Series.

Year.

1116 1113, England so hot that corn and forests took fire. Red dust 1117.

1059 Famine in Egypt in 1859 (*Enc. Brit. Fam.*)—in Modern Egypt the date is given as 1064. Rise in river failed for seven consecutive years; in two provinces half the people died. (B and E combined.)

1040 No record.

1021 Excessive heat and drought in England. 1020, great drought in India, and in Central America it lasted six years. (*Abbé Brasseur de Bourbourg*—"*History of the civilized nations of Mexico and Central America*," Paris 1857.)

1002 1000, the wells, water courses, and lakes were all dried up. (*Eng. Mech.*, xxxix., p. 506.)

869 Red dust 869.

850 850 to 851, drought in Italy and Germany.

774 775, drought and excessive heat in England after great frost. 772 great drought in Ireland.

755 No record.

736 737, great drought in Britain.

679 680, drought in England for three years.

603 605, drought and scorching heat in England.

584 Red rain fell.

451 Great drought Eastern Europe, Phrygia, Galatia, Cappadocia. This was probably an extension of D into E.

375 374, drought and famine in England.

299 298, great drought in Wales.

Discussion.

Professor Gurney said:—Though neither astronomer nor meteorologist, I should like to offer a few remarks on Mr. Russell's paper, taking points in order, as they strike me. In discussing the weather of this Colony, Mr. Russell says, "The years were simply classed as good or bad, the question of how good or bad was purposely left out." What is Mr. Russell's definition of a good year

or a bad one? He has apparently thrown over his rainfall and temperature statistics, and his bald statement that such-and-such a year was good or bad seems far from convincing. I am afraid that the diagram which he shews us to-night, based upon these statements, is useless, if not misleading. I object also to another detail in the diagram. Mr. Russell "draws a vertical red line through A *between the first and second years*." He says that the interval "was regular and exactly nineteen years." Also this so-called A drought varies in its length, "lasting from three to seven years." It follows that a line drawn so as to mark *the middle* of an A drought would not have recurred at equal intervals of nineteen years. Yet the middle seems to me a more natural datum line.

Again, periodicity cannot be shewn by picking out a drought in Egypt, another in India, and a third in Australia, all happening at different times. Mr. Russell distinctly lays down as his thesis "the salient points (in the weather) in our century are repetitions of the salient points in all past times, and probably in all countries." To prove this he must produce evidence of a constantly recurring period in Egypt, of an identical period in Australia, and so on, independently. This he has not done.

I myself have examined certain weather statistics, published in Vols. XVIII. and XXI., of the "Smithsonian Contributions to Knowledge," which refer, in one case, to the 'Precipitation of Rain and Snow,' and in the other, to the 'Average Temperature, over a considerable part of the United States of America. These volumes I lay before you to-night. The first table shews minima in 1818-9, 1836-7, 1856—just enough agreement with a nineteen years' cycle to tantalize—but the other minima do not conform to such a cycle, nor do the maxima. In the second table minimum temperatures occur in 1785, 1797, 1816, 1835, 1857, 1868, and maxima in 1793, 1802, 1826, 1845, 1865. Mr. C. A. Schott, who compiled these tables says, "the average of the longer waves is about twenty-two years." I would point out that such an average does not assist Mr. Russell in any way, but quite opposes

his conclusions. He refers to the moon as the "exciting cause," and he presumably has in his mind therefore the Metonic cycle of two hundred and thirty-five lunations, which gives a period of nineteen years so exactly, that an average error of even a few months is out of the question.

This Metonic cycle of nineteen years has been known to the astronomers of the civilized world for more than 2000 years. Greeks, Romans, Egyptians, all were acquainted with its undoubted accuracy. Surely, if this same cycle obtained as regards the annual overflow of the Nile, it would have been known to every Fellah in Egypt for the last 2,000 years. Such knowledge, once gained, could never be lost. The prosperity or adversity of the whole country depended upon this yearly flood; its approach was heralded to an expectant populace by swift messengers; its absence spread misery throughout the land. I conclude that it is highly improbable that a nineteen years' cycle has existed for the Nile-flood within historic times.

It is impossible to deal seriously with the evidence which Mr. Russell draws from Biblical meteorology. The dates given in the margins of some English bibles are foreign to the text, and have no scientific value. Supposing the dates are trustworthy which Mr. Russell gives from Greek and Roman history, they frequently seem to miss his datum line by from one to four years, and Mr. Russell's cycle is so full of different droughts that it seems easier to hit a drought somewhere than to miss altogether. He actually says in one place "It is worth mentioning that in India from 503 B.C. to 443 B.C. there was great drought and pestilence, and these dates are in the D series." It seems to me that a continuous sixty years' drought would completely efface three cycles and part of a fourth.

The picturesque description which is given of the peculiarities of a drought in New South Wales is no doubt quite accurate; but it does not help the argument, and I can only conclude by saying that Mr. Russell has produced no satisfactory evidence that a nineteen years' cycle exists in the weather of the world. Not-

withstanding this conclusion, I think Mr. Russell has provided us with an extremely interesting paper, and I hope that these remarks upon its subject-matter do not exceed the limits of fair criticism.

Mr. D. M. MAITLAND, said that in a country dependent almost entirely on its pastoral and agricultural interests, the question of periodicity of seasons was of vital importance. There were some points in the paper, or rather in the diagram illustrating it, that he thought required further explanation. The year 1857 was shewn as about the middle of a dry cycle, of the D series, but on the coast at any rate the rains were very heavy; in June, July, and August of that year, there occurred the highest floods of which any authentic records had been kept up to that time, those present might remember that the "Dunbar" was wrecked in the August of that year. Again in 1866, the year the "Cawarra" was wrecked, which is shewn as a dry year in an A cycle, very heavy floods occurred. The year he desired to call attention to particularly was 1867, (shewn in the middle of a dry cycle) of which the rainfall record at the Observatory was sixty-nine and a half inches, at Melbourne the same year, the rainfall was above the average, and if his memory served him correctly, the register at Greenwich also shewed a rainfall higher than usual. That year would long be remembered in this Colony, from the fact that the most disastrous flood ever experienced in the valley of the Hawkesbury took place, the water rising at Windsor to a height of sixty-two feet above ordinary level. That year being apparently an exceptionally wet one, he would like to know whether its insertion in a dry cycle was an error or whether the records from other places indicated that the rain supply was so scanty elsewhere as to justify its insertion in a dry term, notwithstanding the large rainfall in Sydney, Melbourne, and in England.

Mr. P. N. TREBECK, said that the existence of a nineteen year cycle had been referred to by the late Rev. W. B. Clarke, as would be evident from the following extract from the *Sydney Morning Herald* of 1st May, 1846 :—"The Rev. W. B. Clarke in a recent

communication to the *Sydney Herald*, expresses his opinion that Sturts' desert, Leichhardt's experience of little or no rain even in the tropics, Sir T. L. Mitchell's sufferings on the Bogan from want of water, and the state of the Colony generally, prove this to have been a year of drought parallel with the season of 1826-7, and certainly adding another link to the chain of facts for establishing an atmospheric cycle of nineteen years"

Prof. THIRELFALL said:—Mr. Russell's statement as to what constituted a good or a bad season is somewhat indeterminate.

(1) An exact definition of the difference between a drought and a good season was essential, otherwise there must be a fundamental uncertainty in the investigation. A farmer or pastoralist may be supposed to do well or ill according to a variety of circumstances, amongst which rainfall is no doubt a prominent but not over-powering factor.

(2) The records of Australia have, as I understand, only been kept with anything like adequate care for about five and twenty years, while the period decided on by Mr. Russell is nineteen years. Hence the observations have not really extended over more than a period and a third, and this is rather too little to form a foundation for such a wide generalization. Before the records were kept properly, the evidence as to 'good' and 'bad' years may have involved other than meteorological factors.

(3) With regard to the historical evidence advanced in which droughts are cited sometimes from Europe, sometimes from India, leaves it uncertain whether there is a drought *somewhere* every nineteen years, or whether droughts recur at the *same place* every nineteen years.

(4) The statement in the paper, that Egypt like Europe seems to get its change of weather a year earlier or later than Australia, should appear in the historical evidence as drawn indifferently from Europe and India and run on the Australian records.

(5) These criticisms apply to droughts of the A series only. The evidence for the other series is on Mr. Russell's own shewing not sufficient to establish any periodicity at all.

(6) Whether the cycle of nineteen years be accepted or not, I consider that Mr. Russell's investigation has brought many interesting points to light, and that the method of comparing evidence collected from all parts of the world, exhaustively employed, can not fail to advance our knowledge of meteorology, and that Mr. Russell is to be complimented on having made such a plucky attack on a difficult subject.

Mr. Carmen't said that he would like to ask Mr. Russell whether his contention was that droughts prevailed over the whole of the world at once in accordance with the nineteen years' cycle; and whether or not he contended that the eclipses of the moon had any real connection with the atmospheric changes which were concerned in producing droughts. He would also like to ask why the vertical red lines in the diagram were drawn after the end of the first year of each of the A droughts, seeing that the successive intervals would have been just the same if they had been drawn at the commencement of the drought in each case. Again, it was not at all clear from the paper what had induced the author to construct precisely *five* different series of droughts and neither more nor less. It was clear that with a sufficient number of different series, each of which might last for several years, *any* previously recorded drought would fit into one or other of the given series. Further, the author had not given any data in his paper which would enable an independent observer to come to a conclusion as to the propriety or otherwise of any given year being classed as a *good* year or a *bad* year; and as regards the various historical droughts cited, one would require much more extensive information, as to the *nature* and *value* of the evidence available in support of the alleged facts set forth, before being able to accept them as a foundation on which to base any theory of periodicity. In regard to the question of chronology alone and with respect to events which happened in prehistoric times, Mr. Russell had himself admitted that the dates were quite uncertain, and yet proceeded to found conclusions upon them in support of his theory.

Professor David said that, with regard to Mr. Russell's nineteen year weather cycle he had collected some statistics as to the

times of occurrence of some historic earthquakes and violent cyclones, the dates of which were authentic, with a view of ascertaining whether they supported the nineteen year weather cycle. The dates of the events referred to range from 1692 A.D., the great Jamaica earthquake, to 1886 A.D. the date of the eruption of Tarawera. Out of the fourteen events here recorded, three were violent cyclones in the Bay of Bengal, unaccompanied by earthquakes, one a violent cyclone in the Bay of Bengal accompanied by an earthquake, and the remaining eleven violent earthquakes. Of the four cyclones of phenomenal violence and extent one was at the commencement of an "A" drought, (so called in Mr. Russell's paper), one at the end of an "A" drought, one at the middle of a "D" drought, and one during an "E" drought. Of the twelve violent earthquakes, five were during or very close to a "D" drought, three occurred during an "A" drought, and four do not appear to have been connected with any of the drought periods referred to by Mr. Russell. Although the evidence might be considered inconclusive, it appeared probable that great cyclones and violent earthquakes were more frequent during droughts than at other times. Several of them fell into the "A" and "D" droughts, though this does not necessarily support the nineteen year cycle.[1]

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[1] The possible relation between droughts and earthquakes may be explained as follows:—The earth is at present constantly radiating heat into space, and secular contraction results from this loss of heat, and secular contraction is probably the chief cause of earthquakes, through the earth's crust at a depth cracking owing to excess of tension. If the annual temperature over the whole earth's surface be raised, outflow of heat would be checked, and earthquake action would be at a minimum. Conversely, if the annual temperature be lowered the escape of telluric heat is accelerated, and earthquake action would attain a maximum intensity; thus theoretically, earthquake action should be more intense in winter than in summer. Mallet's Curve for 5879 earthquakes in the Northern Hemisphere shows that they attained their maxima in January and October, and their minima in June. Out of two hundred and twenty-three earthquakes observed in the Southern Hemisphere the minima were in May and August and the maxima in November, May, June, and July, (as stated by Mr. J. Milne in his "Earthquakes and other Earth

Mr. DEANE said:—Will Mr. Russell kindly inform me where the statement is to be found as to the number of large dead trees which were seen when colonists first landed here? I am much interested in the subject and would like to read the original account of it.

It is somewhat difficult to understand how a meteorological cycle can exist unless accompanied by or resulting from some cosmic cycle. Mr. Russell's cycle of nineteen years corresponds with the Metonic cycle, and a good may persons would be glad if Mr. Russell would explain what that term means. They believe that in a vague sort of way, it implies a recurrence of similar lunar phenomena, but are the phenomena which recur of sufficient importance to account for periodic variations of weather conditions?

I gather from Mr. Russell's remarks that similar eclipses recur at the same time of year after a period of nineteen years, and that when they take place near the equinoxes, droughts seem to result. If the period is an exact one, the centuries can be divided up indefinitely, if not, there must be a gradual transition in the character of the lunar phenomena which ought to be accompanied by an alteration in the meteorological maxima and minima.

Does not the occurrence of eclipses depend upon the position of the moon's nodes? My difficulty is that the period of revolution of the moon's nodes does not correspond with the Metonic cycle. Which period is it that causes the meteorological phenomena?

If the moon has an influence on the weather it can only be by combining its pull on the atmosphere with that of the sun. When

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Movements."—International Science Series, p. 256, London, 1886). It would appear therefore that during the winter months in either hemisphere, earthquakes attain a greater intensity than during the summer months. If this is due to the cold of winter, and if commercial droughts are also droughts in the scientific sense, that is periods when the earth receives less superficial heat, and therefore makes less rain than at other periods, it should be possible to correlate maxima of earthquake intensity with drought maxima. The question, however, is much complicated by the slowness with which certain rocks conduct solar heat downwards, which prevents the wave of summer heat at a particular locality penetrating many feet into the ground until the following winter.

eclipses occur, the sun, moon and earth are in the best positions to produce the maximum effect, and when these occur near the equinoxes we might expect to see some special result, if at other times the sun, moon and earth were a long way off the straight line, but they never are at new and full moon more than 5° off the straight line, and of course generally much less; would such a small difference in angular distance make such a large difference in meteorological effect?

If the result of the combined pull of sun and moon at these particular periods is strong winds, producing droughts in this and some other parts of the world, the increased force of the moist south-west Atlantic air-currents would probably cause a greater deposition of moisture in Western Europe, but it really seems, judging from recent experience, as if droughty weather in Australia is contemporaneous with droughty weather in Europe.

I was much struck with Mr. Russell's array of facts, but the method of deciding whether a particular year belonged to a drought or a good period was not quite clear to the audience, many of whom probably thought that a year with a rainfall up to, or nearly up to, the average, could not be a droughty year, disregarding, however, the irregularity with which the rain fell. A definition of the word drought as applied to this country is very desirable, so that observers might be able to classify the weather with some certainty.

The PRESIDENT asked what convention Mr. Russell adopted to indicate with an approximation to uniformity, the beginning and end of a drought, for the purpose of graphic illustration.

Mr. RUSSELL in reply said:—Professor Gurney asks, (1) "What is Mr. Russell's definition of 'a good year or a bad year'?" The terms good and bad were defined in the paper as those having "sufficient or insufficient rainfall." In the text, page 72, I had shewn by reference to 1895, what a bad year was, and stated "Drought is not wholly made by a shortage of rainfall, its most important factors are great heat and drying winds." I should like to give all the data on which the diagram was based, but it

would cover at least two volumes as large as our annual one, and it could not therefore be included in a paper such as this, and I thought, perhaps I was mistaken, that I could be trusted to go through these records and select the good and bad years. Moreover, I had gone over it once before, and published it in an abstract. My reason for going over it again was to include all the additional matter.

(2) Professor Gurney objects to my making a definite point in a drought, by drawing a line between the first and second year, and points out that it might be drawn anywhere. It may be said here in reply to several questions, a drought is difficult to get hold of, because its limits are not sharply defined like a month or a year in which a day comes, that you pass by the stroke of the pendulum to the next one, it is wanting in defined limits, often drought and rainfall battle for months so evenly, that it is difficult to draw any line, and therefore I took the middle year as the date of the drought; drawing the line between the first and second year, simply to avoid making another line across the record. Now a glance at the diagram shews that out of six A droughts on record four lasted three years or thereabouts, and the second year was therefore at least the nearest to the middle of the drought.

(3) "Periodicity cannot be shewn by picking out a drought here and there." Certainly not, but I have not done so. It is stated in the text that history had been asked for data, which it had been in the habit of neglecting, and that this was admitted to be a weak point, the difficulty of obtaining the data. But it is a very strong point to be able to say, as was done in the text, that all the historical data that I had been able to find in twenty years study, is in favour of the nineteen years' cycle. To my mind this is one of the strongest proofs of the cycle, and I think in legal matters, when *all the evidence* points to one conclusion, the jury is satisfied, even if the evidence is not complete in every point. If it were necessary to prove constantly recurring periods in Egypt, there would be small hope, but is it? The records of the past Nile levels seem to have all disappeared, except for a short recent

period, which, as stated in the text, are very strongly in favour of the cycle, and I must disagree with Professor Gurney's argument that such knowledge once gained in Egypt would never be lost, for the knowledge was not gained by the common herd who survived the downfall, it was known only to the priests, and would in all probability have been lost in the centuries of degradation through which Egypt has passed.

(4) The evidence quoted from Smithsonian Contributions of Knowledge. The minima of snow and rain (*i.e.*, droughts) were in 1818-9, 1836-7, 1856 in America. Let us see how they compare with the diagram; 1818-9 were in D drought here; 1836-7 D drought here began in the latter part of 1836, lasted all 1837 and 1838; 1856, D drought here began in the latter part of 1856 and continued through 1857-8. The evidence here is far stronger in favour of a connection between these North American droughts and the Australian nineteen years' cycle than against it, the more so, when we remember that there is good reason to believe from the records, and from common observation, that the change to drought or to wet weather there is generally a year in advance of the date in the Southern Hemisphere. I have not gone into the question of minimum temperature at all, but of the dates of five maxima in America, three agree closely with our droughts which began in 1826, 1845, and 1865. It is evident therefore, that had Professor Gurney looked a little more closely he would have found confirmation not contradiction.

(5) Now as to what the Professor calls "Biblical Meteorology" "which it is impossible to take seriously," the point cannot be passed over so lightly. I know in common, I suppose, with every one who has read anything about chronology, that the dates in question are generally taken to be guesses at the probable dates, an uncertainty which I indicated at the time; but the facts remain, first, that whatever the chronologists did, the intervals between those droughts and ours are multiples of nineteen years, within the limits of the droughts; and second, that the intervals amongst them are either exactly nineteen years or multiples of

nineteen years; the same remarks apply to the other B.C. droughts. I rejected one of them, and gave the reason for doing so: the remaining seventeen all support the nineteen years' cycle. The drought in India 503 B.C. to 443 B.C. when we come to look into it, is not such a remarkable occurrence, for we find from the carefully kept meteorological records of England, that last century, *i.e.*, from 1738 to 1762 *a period of twenty-five years*, there was a drought in England, in which the average rainfall for the whole period was only 78% of the average; four years of this period, 1740-41-42-43 were exceptionally dry, the rainfall only amounted to 63% of the average, and perhaps it will seem remarkable, but according to the nineteen years cycle, part of 1740, all 1741-42 and part of 1743 must have been a drought in New South Wales. Again other four years of the English period 1759-60-61-62 made a drought with an average percentage of rain of 76 or 24% below the average, and again we find the computed drought for Australia part of 1759, all 1760-61, and part of 1762. It is obvious therefore that there can be long periods of drought in England as in India, and that in them there may be intensified periods of the drought, the dates of which would be chronicled and fit into the nineteen years' cycle. These facts seem to me to be strongly in favour of the nineteen years' cycle instead of against it as the Professor thinks.

(6) The Professor says, "the cycle is so full of different droughts that it seems easier to hit a drought somewhere than miss altogether." I collected many facts about these minor droughts, and have good reason to believe that I could, for some short intervals, shew that the great and little droughts in the northern hemisphere could be shewn to be in the same order and relation as they are in Australia, but I thought that there was not evidence enough to be convincing, and I omitted them as they were not material to my purpose, and took the two major droughts, and have proved that they have recurred very frequently in their order. Had I taken one only, it would have been enough for my purpose, *i.e.*, to prove that a certain phase of weather recurs, but

I did take only the two major droughts about which history has something to say.

(7) Mr. Carment asks if I contended that droughts prevailed over the whole of the world in nineteen years' cycles? That was what I meant to convey as my conviction, but as pointed out, nearly the whole of the world had no history of such matters, and it could not at present be proved. See list of droughts under date 1876, appendix 2.

(8) As to the effect of eclipses of the sun and moon on weather. I said in the text that the investigation as to the moon was unfinished, but that, so far as the comparison of the moon's position, in relation to the sun and earth and droughts, goes, it shews that when the eclipses occur about the equinoxes, that is, when both sun and moon are making the greatest tides in the ocean, then we have droughts, due possibly to their combined influence on the earth's atmosphere.

(9) Mr. Carment—"It was not clear from the paper what had induced the author to construct five different series of droughts." A reference to the text shews that I did not construct them. The years were studied and classified without reference to any cycle, and when this was done, the diagram was complete with its good and bad years all shewn, the theory followed to account for the order in which they recur.

(10) As to what constituted a good or bad year, see (1) in reply to Professor Gurney. And in regard to the statement that it did not appear why the author had constructed five different series of droughts, see my reply (6).

(11) And as to the question of chronology see (5).

(12) Mr. Maitland, I think correctly appreciates the importance of the nineteen years' cycle, but does not see how great rains and floods form parts of droughts. In the text I have endeavoured to shew that places with large rainfall, as the coast of New South Wales, do not feel the severity of drought, and that hurricane storms are in some way connected with droughts, and such storms

travelled down our coast in 1857 and 1866 depositing deluges of rain on the coast, while inland drought reigned supreme; these are the phases of what I have called in the text "breaks in droughts."

(13) Mr. Trebeck's quotation is support from a very close observer of nature, and could we find a full statement of the late Rev. W. B. Clarke's opinions on this subject they would be invaluable.

(14) Professor Threlfall's criticism (1) is I think answered in my reply (1). In answer to (2), (3) and (4):—No, the complete meteorological records go back only twenty-five years, but newspapers and histories have enabled me to carry the record back to the foundation of the Colony, see my replies (1) and (3).

(15) Professor Threlfall (5), said his criticisms apply to drought A only. The evidence for the other series is on Mr. Russell's own shewing, not sufficient to establish any periodicity at all. This does not represent my contention; I claim that droughts A and D are in the nineteen years' cycle, the others I did not discuss; see my reply (6). History seldom records any but the major droughts A and D. The recurrence of these in a nineteen year cycle is I think, proved beyond question, if the fact be remembered that there was in past ages no meteorology, and a record of drought only when very intense or the cause of some disaster. If these occasional records ALL prove the cycle, as I have shewn that they do, then the probability in its favour is so strong, that, to my mind it is proof of the fact.

(16) Mr. Deane asked, where the story about dead trees was to be found. References to this fact in my book on the "Climate of New South Wales," 1876, pp. 66 and 181.—(*Royal Society, N.S. Wales*, Vol. x., p. 165, 1876.)

A full reply to Mr. Deane's further questions can only be given on the completion of the investigation into the cause of droughts, and I regret that this is not far enough advanced to enable me to reply; evidence sufficient to convince me as to the moon's

influence has, however, been obtained, as indicated in the text, and I hope that when completed it will amount to a demonstration; I may, however, say here, that I do not think eclipses, as such, have any appreciable influence on droughts.

The President asks, "What convention Mr. Russell adopted to indicate with an approximation to uniformity, the beginning and end of a drought for the purpose of graphic illustration." The only guide as to the boundary line between good and bad years was the time when sufficient rain ceased, which marked the end of good weather, which as the diagram shews was very frequently not the end of a year, but often was the time of equinoxes; sometimes the change comes in other months, but the tendency is for a change to come about March or September, the times of equinox; when thus determined, the diagram was plotted accordingly, shewing as nearly as the size of the diagram permitted, the time of year at which the change took place.

The Rev. Dr. Wyatt Gill, who was for thirty-three years a missionary in the Cook's group of Islands, and knew from his predecessor, what the weather had been for seven years before he went, gives me as his contribution to the discussion on my paper, some valuable notes as the result of that forty years experience. He says, that in those islands hurricanes came in droughts, and 'he knew that they were in for a hurricane if there was a drought in summer,' and the natives of Mangaia, who are keen observers, if asked about the weather repeated their proverb, "*Kare e roto, ka ta te āā ra,*" which translated is, "should there be no flood there will be a hurricane." This then was the result of generations of close observation by those whose lives to a large extent depended upon it. Unquestionably a heavy flood in those islands is a *far less* evil than a cyclone, because the flood secured sufficient moisture for the "Taro"[1] which constitutes the staff of life on Mangaia, and at that period *no* supplies of food were obtainable from any *outside source.* About the year 1813 a terrible famine resulted from long continued drought in the island of Mangaia. Probably

[1] *Caladium petiolatum.*

a half, certainly one-third of the population died in consequence of that drought. In December 1831 a most severe cyclone was experienced at Rarotonga and Mangaia: on the island of Rarotonga 1,000 houses were destroyed. In March 1846, a fearful cyclone took place desolating the entire group of islands. On March 27, 1866, another fearful cyclone devastated Mangaia, destroying two hundred and sixty-eight houses and uprooting 2,000 cocoa-nut palms; Rarotonga suffered in the same cyclone, but not so severely as Mangaia.

THE "MIKA" OR "KULPI" OPERATION OF THE AUSTRALIAN ABORIGINALS.

By T. P. ANDERSON STUART, M.D.,
Professor of Physiology in the University of Sydney.

[With Plate VI.]

[*Read before the Royal Society of N. S. Wales, June 3, 1896.*]

IT was Miklouho-Maclay who appears to have been the first to adopt the term "Mika."[1] Howitt proposes to give the name "kulpi" to the operation from the name given to the initiate among the Dierie blacks of the Cooper's Creek district.[2] The custom was first noticed by Eyre,[3] in the country around the Great Australian Bight: it practically consists in, generally at the age of puberty, cutting the lower wall of the urethra so that it is slit completely open from below, the cleft sometimes extending only half way back, sometimes the whole way back to the scrotum. The organ then is no longer a tube. Sometimes a mere perforation is made as hereafter noted.

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[1] Zeitschrift für Ethnologie, Bd. XII., 1880, Verhandl. p. 85.

[2] Journ. Anthrop. Inst. xx., p. 85.

[3] Eyre, Journals of Expeditions of Discovery into Central Australia, 1840-41, 2 vols., London, 1845.

In a paper which was for the immediate purpose of describing certain stone implements or knives used by the blacks of the Mulligan River in performing the operation, R. Etheridge, Jun., in 1890, gave an account of what had up till that time been written on the subject of this curious and interesting custom,[1] because as he said, "there still (1890) seems to be much scepticism and ignorance on the subject." I shall, therefore, but briefly refer to the operation before describing the photographs of the actual condition which it is the main purpose of this note to record and publish.

In 1879, Dr. Milne Robertson, Surgeon of the Convict Establishment in Western Australia, sent a photograph of the organs of an aboriginal, who had had the operation performed, to the Exhibition in Sydney, but this photograph is believed to have perished in the fire which destroyed the entire building and its contents. Recently Sir John Forrest, the Premier of Western Australia, at my request, caused a search to be made for the negative or a print from it, but failed to find either, and as, so far as I can ascertain, no photograph or drawing of the condition had ever been published I venture to publish two which were taken under my own superintendence.

Dr. Milne Robertson[2] describes the slitting of the urethra to be from the meatus to the middle of the organ only, in the case of the De Grey River blacks, while in the case of those living on the north side of the Murchison, the cleft extends from the meatus to the scrotum. The latter condition is identical with that of the subject of my photographs. In other cases, as in that of the blacks of the Gawler Range, the operation is a mere perforation of the lower wall of the urethra "at the base of the scrotum,"[3] that is anterior to the scrotum, in the penial portion, as is expressly

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[1] Notes on Australian Aboriginal Stone Weapons and Implements.—Proc. Linn. Soc. of N.S.W., 1890.

[2] Report upon certain peculiar Habits and Customs of the Aborigines of Western Australia, Perth, 1879.

[3] Le Souëf—see Smyth's Aborigines of Victoria, 1878, Vol. II., p. 205.

stated by Creed,[1] who gives the opening as being from one to one and a half inches long. So also Lumholz,[2] who says that the Georgina River blacks make a similar opening an inch long in the same position, and Provis[3] gives half an inch.

The incision is made with a sharp edged piece of quartz, shell, flint, or, in more recent times, glass. These fixed with resin, twine etc., into handles constitute the "mika-knives." The bleeding is stanched with sand,[4] and the edges of the wound are burnt, Lumholz says, with hot stones—perhaps, as Etheridge suggests, to cauterize them—and are kept from adhering again and healing by being kept apart with bits of stick, wood, bark, or bone inserted between them, or by being filled with clay,[5] or by being rubbed with a broad edged stone. The result is a permanent slit, cleft or opening. Stretton speaking of Leeanuwa tribe, Borroloola, Northern Territory, says that no dressing is used.[6] Palmer[7] states that amongst the Kalkadoona of Central Queensland, the urethra is said to be sometimes "taken out," that is "cut out" after the wound is healed, that is after the wounds from the operation of slitting of the urethra are healed.

The time of life at which it is done varies very much; eight days is the soonest I have seen recorded, then ten years, fourteen years, eighteen years, and lastly the man may first be the father of two or three children, and then be operated upon. In some tribes all the males are said to be operated upon, in others some are left unoperated upon. In that case sometimes the strong and able bodied are selected for operation, sometimes they are those that are left intact.

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[1] J. M. Creed—Australasian Medical Gazette, Vol. II., 1883, p. 95.

[2] Lumholz—Among Cannibals, 1870, p. 48.

[3] Police-Corporal C. Provis, speaking of the natives of Port Lincoln in Taplin's Folklore, Adelaide, 1879, p. 99.

[4] Howitt—Journ. Anthrop. Inst., XX., 1890-91.

[5] Ravencroft—Trans. Roy. Soc. S. Aust., XV., 1892, p. 121.

[6] Trans. Roy. Soc. S. Aust., XVII., 1893, p. 232.

[7] Journ. Anthrop. Inst., XX., p. 85.

As to the aim of the operation it is impossible to come to a definite conclusion. Dr. J. C. Cox,[1] says the object of the operation is "difficult to surmise." Some writers merely refer to it as an "operation," *e.g.*, the "terrible operation" of Sturt, thus involving no theory; others again regard it as a rite or ceremony merely, *e.g.* the "incredible ceremonial" of Lubbock, the "most extraordinary ceremonial" of Eyre (*loc. cit.*), the "terrible rite" of Curr.[2]

C. W. Schürmann,[3] a missionary, who appears to be the second observer to record this custom, writing of the aboriginal tribes of Port Lincoln in South Australia, says, "the object of this strange mutilation I have not been able to ascertain. In support of a practice so essentially barbarous the natives have nothing to say more than that 'it was observed by their forefathers, and must therefore be upheld by themselves,'" here apparently it is now, at all events a pure rite or ceremony. Froggatt,[4] says "the only reason I could learn for this curious mutilation is a statement of an old man, that until it was done "they were all the same dog (or other animal)," meaning I suppose that they were not really men till they had been operated upon, they were no better than dogs or other lower animals. Howitt, *(loc. cit.)* speaking of the important Dieyerie tribe in Central Australia, says that this tribe names anyone the subject of this operation "Kulpi," and that "it is only when a young man has been made kulpi that he is considered to be a "thorough man," and in this sense kulpi is the highest stage of the initiation ceremonies. A kulpi has the privilege, and he alone, of appearing before the women in a perfectly nude state. It is to the kulpis that important matters bearing on the welfare of the tribe are entrusted, and they always take precedence of the other men who are not kulpi. They hold in fact the most important positions,

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[1] Proc. Linn. Soc. N. S. Wales, 1881, p. 663.

[2] The Australian Race, 1886, I., p. 72.

[3] Aboriginal Tribes of Port Lincoln in South Australia, Adelaide, 1846.

[4] Proc. Linn. Soc. N. S. Wales, 1883, p. 652.

and powerfully influence the government of the tribe. The headman, Jalina Piramurana, in complimenting a kulpi on the satisfactory manner in which he had accomplished some mission or matter which had been entrusted to him, was accustomed also to refer to his being a kulpi. All men sent on special missions to other tribes are kulpi. It would never be even thought of to send a non-kulpi in charge, as he would not carry much weight or have such influence as a kulpi, Men often express regret that they are not kulpi, feeling some jealousy of the superior position of those who are so distinguished, for the kulpis also take precedence at the grand corroborees, where they are the principal leading dancers and also are "masters of the ceremonies" generally. The Dieri say, according to Mr. Gason, that the object of the kulpi operation is "cleanliness," and that without it no one can be a "thorough man." "

Hardman,[1] who was geologist to Forrest's Kimberley Expedition and a keen observer, says that it can hardly be considered from a Malthusian standpoint, because "every boy is so treated, and the married men have no lack of families." He thinks it may have arisen from some case of stricture, or may perhaps be "simply some ancient rite connected with Phallic worship."

Foelsche[2] says that he was told by a Mr. Lautour that he was told by the women that the men so operated upon, though not impotent, could not beget children, and so on that account were preferred, and Mr. Lautour also said that it was considered as a mark of honour. Scarcity of food has been suggested as a cause, inducing the members of the tribe to limit their families; but, then again the custom is observed in places where food is plentiful.

Milne Robertson does not believe it is practised in order to limit population; the natives he examined were very fond of children and had abundance of food in their country. "For my own part," he says, "I am inclined to think that these operations

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[1] Proc. Roy. Irish. Acad., 1881, I. (3) No. 1, p. 73.

[2] Trans. and Proc. Roy. Soc., South Australia, Vol. v., Adelaide, 1882.

were first performed to give relief in cases of inflammation of the urethra, and that this rude surgery gradually became a custom." He argues, from the occurrence of hypospadias and the mode of development of the urethra, the comparative morphology and analogy of the organs, and from the fact that so little spermatic fluid is required to impregnate, that the operation is not really effective and is not really practised for the purpose of limiting reproduction.

Miklouho-Maclay[1] says that his correspondent, Herr Rotsh, told him that on the Herbert River the aborigines told him it was in order not to have too many children, and this is supported by another custom there, the pulling out of the nipples of young women. Sometimes the nipples are cut off so that if a child is born it shall not be suckled and will die, for they have none of the artificial means of feeding infants that we have.

The subject of my photograph was from the spinifex district of North Australia. I show you whole length photographs of him, that prove him to be a strong well-made, lusty fellow. The great cuts on the outer sides of the thighs and the tatooing of the abdomen, breast, shoulders and arms prove him to be one of a very savage and barbarous tribe. He was a difficult subject, and I was obliged to have two photographs of his genitalia made in order to show the condition fully. It is seen that we have here the result of the operation in its fullest extent, the cleft extending right up to the front of the base of the scrotum, where the round opening seen is that of the urethra. The urethra in front of this is widely opened, and it is not even a groove, for the corpora cavernosa project so that instead of being concave the urethral roof is actually convex. In the photograph, where the man himself is holding the organ, it is seen that the skin edges are pulled away to the side and the urethral surface is thus enormously extended: in the other photograph, where I am holding the organ in a suitable position to show the glans, the wrinkling of the urethral mucosa, due to its being so extended, is clearly seen.

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1 Zeitschrift für Ethnologie, Bd. XIV., 1882, p. 27.

The prepuce was intact, there having been no preliminary circumcision as sometimes occurs. The exposed urethral mucosa had the bluish, injected, hardened appearance common to mucous membrane in such circumstances. The man had a considerably urinous odour, in fact he was anything but a pleasant companion to the photographer! That is not difficult to understand, when we think of the amount of wetting of the parts adjacent to the orifice which must almost necessarily happen at each micturition, and of the fact that in Sydney he was not so lightly clad as he would most likely be on his native heath. As to the actual manner in which micturition is performed Miklouho-Maclay[1] says that it is in an upright position, the organ being raised by the hand and the legs widely separated.

As to the origin of the custom we can now only surmise, but these possibilities suggest themselves, viz.—1 Quite certainly hypospadiacs would be met amongst the aboriginals, who would not, and could not faiì to notice the condition. May not some aboriginal naturalists and philosophers have noted that, when the malformation did not actually prevent copulation, the seminal fluid escaped to an unusual extent, and that such unions were followed by unusually few children? This of course raises the crucial point *is* the Mika operation associated with limited reproduction? Before discussing this I shall note the other possibilities.

2. What is more likely than that in such a life as that of the aborigines, wounds and lacerations of the urethra should occur, be badly tended and in the end lead to permanent fistulas more or less extensive, or do not often fistulous openings result from disease of these regions? Dr. Milne Robertson suggests that rude surgery for the relief of inflammation may have formed the starting point. Here again, the aboriginal observer would come in, for he might be supposed to notice the escape of spermatic fluid through the opening.

3. May there not have been a deliberate and well reasoned out operation undertaken for the express purpose of letting the fluid

[1] *Loc. cit.*, Band XII., p. 86.

escape? This seems to me quite probable, for we know in very many ways that the aboriginals ascribe to the fluid the most wonderful life-giving qualities, and they are quite capable of such reasoning. Moreover, there is direct evidence of the validity of this suggestion, for I have often been told by pioneers and others that the aboriginal women deliberately empty the vagina after coition, with the view of preventing inpregnation. The power of the fluid to impregnate is thus clearly recognised.

If the custom is not to be considered as a mere rite, the question of utility or effect must be discussed. The statements of the blacks themselves, as we have seen, do not permit of any certain conclusion to be drawn. White observers, too, give unsatisfactory accounts, some say that it really limits production, some that the children are just as numerous, some make no remark on that head at all.

Miklouho Maclay's informant Mr. B—— told him that he had actually seen the fluid escape *in coitû*, and this is indeed what one would expect from the state of the parts. Milne Robertson argues that the edges of the groove will be brought together *in coitû*, and so a sort of temporary channel be established as in birds. Contemplation of the subject of these photographs leads me to the opposite conclusion; it seems to me, rather, that the bulging corpora cavernosa will open the urethral groove wider and wider. Indeed is is wholly misleading to compare the natural corpus spongiosum of birds to the mutilated spongy body of these men. I believe, then, that the condition does prevent the entrance of the full charge of the fluid. This, however, does not imply absolute sterility, for it is of course well known that an extremely small quantity of the spermatic fluid is necessary to fecundation. It is also known that if the fluid merely bathe or touch the external parts the spermatozoa can make their way up the whole length of the passage by their own motion and so effect fecundation. But in the mika condition the base of the intromittent organ and the pudenda will be so bathed in the fluid that the movements of the parts will certainly smear the lower part of

the vagina with it. Further, we are told, and it is certainly the case in the subject of my photograph, that the release of the corpora cavernosa below permits the organ to be flattened and widened, especially during erection. This will itself tend to widen the vaginal orifice and so permit the fluid to enter more easily. Thus while the imperfection of the tube prevents all the fluid being lodged well within the passage, a quantity will certainly be left within the lower part of it. In my opinion therefore, it is a question of degree—in the normal condition a large quantity is left in the passage, in the mika condition it is a small quantity.

What then is the probable effect of this diminution of the quantity of fluid introduced? I think there will generally be upon the whole, lessened chance of fecundation, but in particular cases it *may* not be very marked at all, and the recorded observations as to the number of children in the camps of mika-practising tribes support this view, which, however, is opposed to the opinions expressed by many writers. Creed,[1] for instance, regards the mika as the "most perfect form of "Malthusianism practicable," and says that "impregnation is impossible, and this effect seems to be the desired end for which the operation is performed." Eyre however, who first described the condition, does not go so far as that. He says, "this extraordinary and inexplicable custom must have a great *tendency* to prevent the rapid increase of population, and its adoption may perhaps be a wise ordination of Providence for that purpose, in a country of so desert and arid a character as that which these people occupy."

Taking everything into consideration, I conclude that—

(1) Nothing whatever can be definitely stated as to the origin of the custom.

(2) The operation does not necessarily render the man sterile. It merely diminishes his fertility; what the degree of diminution may be will depend entirely on circumstances.

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1 *Loc. cit.*, p. 95.

NOTE ON THE ABSORPTION OF WATER BY THE GLUTEN OF DIFFERENT WHEATS.

By F. B. GUTHRIE, F.C.S.
Chemist to the Department of Agriculture; Acting Professor of Chemistry, Sydney University.

[*Read before the Royal Society of N. S. Wales, June 3, 1896.*]

THE property possessed by flour of absorbing water, known technically as the strength of the flour, is known to vary considerably in different samples. In order to produce a dough of a given consistency, flour from different grain takes up quite different proportions of water. This is a factor of the greatest importance to the bread-maker and consequently to the bread consumer as well as to the miller and farmer, since upon it depends the volume and lightness of the baked loaf.

In the course of an investigation into the milling qualities of different wheats,[1] it was observed that the water-absorbing power of the flour from different grain, varied in many cases quite independently of the gluten content. As it is not unusual to regard these two properties as identical, and to assume that the strength of a flour depends upon the quantity of gluten it contains, I append a few examples of the discrepancies then observed. The figures relating to strength are expressed as quarts of water absorbed by a sack of flour of 200 lbs., the weight adopted in this Colony.

	Gluten percentage.	Strength.
Triticum Polonicum...	17·75 ...	52·9
Medeah	15·59 ...	46·7
Improved Fife	12·03 ...	63·1
Amethyst	12·03 ...	54·8
Australian Poulard...	11·42 ...	42·7
White Essex	10·00 ...	58·9
Purple Straw	8·83 ...	47·8
Vermont	8·58 ...	40·9
Northern Champion...	7·97 ...	49·0

[1] Agricultural Gazette of N. S. Wales, March, 1895.

From the above results it seemed not unreasonable to suppose that this property of absorbing water depended rather upon the nature of the different glutens than upon their actual quantity.

This supposition was moreover strengthened by the fact, noticed during the course of the experiments referred to, that the glutens obtained from the strong flours were as a rule rather tough and elastic, coherent, but not adhesive ; the weak flours, on the other hand yielding a gluten which was soft, tenacious and inelastic. The glutens of this class of flours when superficially dried, adhered to everything which came in contact with them, they could be drawn out and remained out of shape when the tension was relieved. So general is this, that although the terms soft, adhesive etc., used to express the nature of the glutens, are arbitrary terms and not referred to any exact scale, yet if we arrange the list already given in the order of their water-absorbing capacity we find this property follows closely the physical nature of the gluten

Variety.	Strength.	Nature of Gluten.
Improved Fife ...	63·1	soft, non-adhesive.
White Essex... ...	58·9	med. hardness, non-adhesive.
Amethyst	54·8	hard, non-adhesive.
Triticum Polonicum...	52·9	soft, adhesive.
Northern Champion...	49·0	soft, adhesive.
Purple Straw... ...	47·8	soft, adhesive.
Medeah	46·7	very soft, very adhesive.
Australian Poulard ...	42·7	very soft, very adhesive.
Vermont	40·6	very soft, very adhesive.

Assuming then that the adhesive or sticky glutens are characteristic of the weak flours, and the non-adhesive and coherent glutens are characteristic of the strong, it remained to be seen if any connection could be established between these properties and the chemical constitution of the glutens, in other words what constituent of gluten determined the water-absorbing property of the flour. The following notes are an attempt to elucidate this question.

In 1893, Messrs. Osborne and Voorhees published the results of their investigations into the nature of the proteids of the wheat-kernel.[1] In the course of a long and careful series of experiments they established, among other interesting points, the fact that the gluten of the wheat-kernel consists of two proteid substances, one soluble in weak alcohol, the other insoluble. To these proteids they gave the names gliadin and glutenin respectively. The grain they experimented upon was of two kinds, Scotch Fife and Fultz. In the glutens from these varieties they obtained 61·5% glutenin and 38·5% gliadin in the case of the Scotch Fife, and 63·2% glutenin and 36·8% gliadin in the case of the Fultz. Both these grains belong to the same class of wheats and contain Fife blood.

It remained to be seen whether the proteids existed in the same proportions in other grain as in those used by Messrs. Osborne and Voorhees, and whether any variation which might be observed in the proportions was coincident with the variation in the water-absorbing quality of the flour.

The wheats selected for the purpose of these experiments are typical of some of the more important families of grain, and those offering striking peculiarities either in the strength or gluten-content of the flour They were sown last year with this particular object in view by Mr. Wm. Farrer of Queanbeyan, a gentleman whose valuable services in the propogation and cross-breeding of wheats are recognized all over the world, and were harvested early in this year. They may therefore be relied upon as pure and true to name, a point of the utmost importance in an investigation of this nature. The wheats were milled by Mr. E. H. Gurney of the Department of Agriculture on the system which we elaborated together and explained in detail in the publication already referred to. To these gentlemen I desire to convey my warmest thanks for their valuable co-operation.

The types selected were the following :—Improved Fife, Hornblende, Toby, Triticum Polonicum, Australian Poulard and

[1] American Chemical Journal, Vol. xv., No. 6.

Bancroft. They were examined for the following points: (1) strength, (2) gluten-content, (3) proportion of glutenin and gliadin in the gluten, (4) physical nature of gluten.

The strength is estimated by running water from a graduated burette upon a weighed quantity of flour until a dough of a given consistency is obtained. This consistency is such that it can be drawn out into long threads and at the same time adheres to the palm of the hand when pressed.

The gluten was determined by making ten grammes of flour into a dough with water, allowing the mass to stand for one hour and removing the starch by working the ball between the fingers in a glass mortar under a running tap. The gluten thus obtained was washed slightly with a definite quantity of ether, introduced into a weighed dish, weighed when wet and again weighed after drying in the air oven at 100° C. to constant weight. In order to be sure that the starch is entirely removed from the dough, it is usually stated in printed directions for gluten estimation that the gluten should be squeezed until a few drops of iodine added to the wash-water fail to produce the characteristic blue colouration. As a matter of fact, although very small traces of iodine can be easily detected by the addition of boiled starch, it requires an appreciable quantity of cold, unboiled starch to strike an immediate blue colour with iodine solution. My experience is that the water is rendered turbid from the separation of starch long after the addition of iodine has ceased to produce an immediate colouration. The glutens in these experiments were always washed until they imparted only the slightest cloudiness to the wash-water.

The determinations of the glutenin and gliadin in the gluten were made according to the method adopted by Messrs. Osborne and Voorhees. Fifty grammes of flour were made into a dough with water, and allowed to stand for one hour, the gluten was extracted in the manner above described, and the wet gluten weighed as a check upon the previous determination. The still moist gluten was then cut up into very small pieces and introduced into a flask containing 300 cc. of seventy per cent. alcohol.

The extraction of the gliadin was continued for four and a half days, the alcohol being replaced by fresh and measured quantities at stated times, so that all the glutens should undergo exactly the same treatment. The alcoholic solutions of the gliadin were evaporated to dryness and the gliadin dried at 100° to constant weight. The insoluble glutenin was introduced into a weighed dish, washed once with alcohol and three times with ether, and dried at 100° to constant weight.

The following are the results obtained :—

Hornblende.

Strength = 56

Gluten { wet = 41·15
dry = 13·09

The gluten of this wheat is soft, elastic, fairly non-adhesive, coherent.

Gluten consists of glutenin = 8·89
gliadin = 3·36
or glutenin = 72·5 per cent. in the gluten.
gliadin = 27·5 „ „ „

Toby.

Strength = 50

Gluten { wet = 38·49
dry = 12·11

The gluten of this wheat is soft, not very elastic, non-adhesive, not very coherent.

Gluten consists of glutenin = 9·01
gliadin = 3·10
or glutenin = 74·3 per cent. in the gluten.
gliadin = 25·7 „ „ „

Triticum Polonicum.

Strength = 48·4

Gluten { wet = 46·67
dry = 15·66

The gluten of this wheat is soft, inelastic, adhesive, non-coherent.

Gluten consists of glutenin = 9·21
gliadin = 6·45
or glutenin = 59 per cent. in the gluten.
gliadin = 41 „ „ „

Australian Poulard.

Strength = 45·4

Gluten { wet = 41·98
dry = 12·97

The gluten of this wheat is very soft, inelastic, very adhesive, non-coherent.

Gluten consists of glutenin = 8·32
gliadin = 4·65
or glutenin = 64·1 per cent. in the gluten.
gliadin = 35·9 „ „ „

These four wheats are typical of four different families of grain, and being all high in gluten content it was anticipated that any differences in the nature of the glutens would be exaggerated. The two first are good bread wheats; Hornblende being a hard Fife wheat, similar to that grown and milled in the United States. Toby being of similar character to the best class of wheat grown in New South Wales. Both these wheats give strong flour, the glutens are elastic and non-adhesive, and it will be seen that in both cases the insoluble proteid, glutenin, preponderates. Triticum Polonicum is not, strictly speaking, a bread wheat, but belongs to the class known as Durum wheats, which are extensively cultivated for macaroni, on account of their high gluten content. Australian Poulard is one of the Poulards which are also not liked for bread making on account of the weakness and bad colour of the flour. These latter wheats it will be seen yield a comparatively weak flour, the gluten being sticky and inelastic, and the gliadin comparatively high.

A further batch of wheats was next examined which had been harvested in the previous year, 1895, in order to ascertain if the differences observed in the gluten content and strength of these

flours when compared with those of flours obtained from this season's wheats were accompanied by a quantitative alteration in the gluten constituents.

Improved Fife (harvested 1895).

Strength = 63·4

Gluten { wet = 32·54
dry = 11·20

The gluten of this wheat is tough, elastic, non-adhesive and non-coherent.

Gluten consists of glutenin = 8·73
gliadin = 2·47
or glutenin = 78 per cent. in gluten.
gliadin = 22 „ „

Triticum Polonicum (harvested 1895).

Strength = 54·0

Gluten { wet = 36·04
dry = 13·20

The gluten of this wheat is soft, inelastic, adhesive, not very coherent.

Gluten consists of glutenin = 9·91
gliadin = 3·29
or glutenin = 75 per cent. in gluten.
gliadin = 25 „ „

Australian Poulard (harvested in 1895).

Strength = 47·8

Gluten { wet = 28·01
dry = 9·80

The gluten of this wheat is soft, inelastic, very adhesive, non-coherent.

Gluten consists of glutenin = 6·94
gliadin = 2·86
or glutenin = 70·8 per cent. in gluten.
gliadin = 29·2 „ „

Bancroft.

Strength = 57·2

Gluten { wet = 26·80
dry = 9·51

The gluten of this wheat is soft, inelastic, adhesive.

Gluten consists of glutenin = 5·91
gliadin = 3·60
or glutenin = 62·2 per cent. in gluten.
gliadin = 37·8 „ „

Improved Fife was selected as being of a similar nature to Hornblende, no grain of this latter variety being available. No grain of the class represented by Toby was obtainable from the 1895 harvest, and comparison of this wheat was therefore unfortunately impossible. Bancroft is a very peculiar Durum wheat, and is the only one I have met with which yields a fairly strong flour, whilst its gluten is sticky and inelastic. It was examined here in order to see whether the chemical nature of the gluten would clear up the anomaly. It will be seen that the gliadin is high as in the other adhesive glutens.

A comparison of the results obtained by the Fife wheat, and by Triticum Polonicum and the Poulard harvested in 1896 with the same wheats harvested in 1895 show the influence of the proportions of the proteids in a very striking manner.

Variety of Wheat.	Year of Harvesting	Strength.	Gluten.	Percentage of Glutenin in Gluten.	Percentage of Gliadin in Gluten.
Fife wheat, represented by Imp. Fife in 1895 and Hornblende in 1896 ...	1895	63·4	11·20	78	22
	1896	56	12·25	72·5	27·5
Triticum Polonicum ...	1895	54	13·20	75	25
„ „ ...	1896	48·4	15·66	59	41
Australian Poulard ...	1895	47·8	9·80	70·8	29·2
„ „ ...	1896	45·4	12·97	64·1	35·9

In all the above cases the flour obtained from the wheat harvested in 1896 contained more gluten than that from the 1895 harvest, but was in all cases a weaker flour, and this appears to be characteristic of this season's harvest. This is directly opposed to the assumption that the gluten content and the strength are interdependent. The explanation is found in the columns giving the proportions of glutenin and gliadin in the gluten. It will be seen that the glutens of the 1895 wheats are all richer in glutenin than the 1896 wheats.

An examination of the separated proteids glutenin and gliadin for their individual power of absorbing water gave the following results. The glutenin and gliadin from four of the glutens, after being dried and weighed were soaked in water until they were thoroughly saturated, the excess of water drained off, and the proteid superficially dried as well as possible.

8·89 grammes dry glutenin from Hornblende gave 15·89 grammes wet glutenin ; absorption = 78·7 per cent.

8·32 grammes dry glutenin from Australian Poulard gave 15·28 grammes wet glutenin ; absorption = 78·2 per cent.

4·18 grammes dry gliadin from Toby gave 6·76 grammes wet gliadin ; absorption = 38·2 per cent.

6·02 grammes dry gliadin from Triticum Polonicum gave 8·96 grammes wet gliadin : absorption = 43·5 per cent.

These results though they agree with the results previously obtained, and show that glutenin is capable of absorbing water to a considerably greater extent than gliadin, are nevertheless not quite satisfactory on account of the difficulty in removing the surface moisture of these proteids, especially of gliadin. I leave them however, subject to future correction, as they are a sort of check on the previous work.

The experiments here recorded point to the following facts.

The strength of water-absorbing capacity of a flour depends directly upon the relative proportion in which the two proteids are present in the gluten.

If the gluten-contents of two flours be nearly the same, that will be the stronger flour which contains the larger proportion of glutenin.

Flours in which glutenin preponderates yield strong, tough, elastic, non-adhesive glutens.

Increased gliadin-content produces a weak, sticky, and inelastic gluten.

It is to be regretted that a larger number of wheats could not have been experimented with. The absence of Purple Straw which is the variety most largely cultivated at present in the Colony, is particularly regrettable. It is however, fairly well represented by Toby. Those examined represent, moreover, types of grain with well marked characteristics as to strength and gluten content, and it was to be anticipated that these would exhibit differences in constitution more distinctly than would grains more nearly resembling each other. Moreover, these could not be obtained until the harvest of 1897, and the results here given are I think, sufficiently definite to justify my bringing them before your notice without waiting until next year.

Appended is a table giving the results in a concise form. For the sake of comparison, the gluten and strength of the 1894 grain is included. It will be noticed that there is a considerable difference from year to year in the nature of one and the same grain. Both gluten content and strength of flour vary in different years, which is no doubt attributable to the nature of the seasons.

Variety of Wheat.	Year of Harvesting.	Nature of Gluten.	Strength.	Gluten.	Glutenin.	Gliadin.	Percentage of Glutenin in Gluten.	Percentage of Gliadin in Gluten.	Proportion of Glutenin to Gliadin.
Improved Fife ...	1894	soft, non-adhesive	63·1	12·03	...	...	...	...	...
„ „ ...	1895	tough, elastic, non-adhesive, coherent	63·4	11·20	8·73	2·47	78	22	100 : 28·2
Triticum Polonicum	1894	soft, very adhesive	52·9	17·75	...	...	...	...	...
„ „	1895	soft, inelastic, adhesive, not very coherent	54	13·2	9·91	3·29	75	25	100 : 33·3
„ „	1896	soft, inelastic, adhesive, non-coherent	48·4	15·66	9·21	6·45	59	41	100 : 62·7
Australian Poulard	1894	very soft, very adhesive	42·7	11·42	...	...	...	...	...
„ „	1895	soft, inelastic, very adhesive, non-coherent	47·8	9·80	6·94	2·86	70·8	29·2	100 : 41·3
„ „	1896	very soft, inelastic, very adhesive, non-coherent	45·4	12·97	8·32	4·65	64·1	35·9	100 : 56
Toby	1894	medium soft, medium elastic and coherent	48·8	9·85	...	...	...	...	...
„	1896	soft, medium elastic, non-adhesive, medium coherent	50·0	12·11	9·01	3·10	74·3	25·7	100 : 34·5
Hornblende	1894	hard, non-adhesive, coherent ...	63·9	11·39	...	...	...	...	...
„	1896	medium hard, elastic, fairly non-adhesive, fairly coherent ...	56	12·25	8·89	3·36	72·5	27·5	100 : 37·9
Bancroft	1894	medium hard, non-adhesive, coherent	60·2	12·89	...	...	...	...	...
„	1895	soft, inelastic, adhesive	57·2	9·51	5·91	3·60	62·2	37·8	100 : 60·7

On AROMADENDRIN or AROMADENDRIC ACID from the TURBID GROUP of EUCALYPTUS KINOS.

By Henry G. Smith, f.c.s.

[*Read before the Royal Society of N. S. Wales, August 5, 1896.*]

At the general meeting of this Society held on June 5th of last year, a paper[1] was read by the author in conjunction with Mr. J. H. Maiden, in which was described the new organic substance "Eudesmin" found by us existing in the kino of *Eucalyptus hemiphloia*, which body (together with another new organic substance existing in the same kino provisionally named by us Aromadendrin) caused the turbidity of this Eucalyptus kino when dissolved in hot water and allowed to cool. We then promised to make a further communication to the Society when the chemistry of this other body (Aromadendrin) should have been worked out. Through the transference of Mr. Maiden to the Directorship of the Botanic Gardens, the work of continuing this research has devolved upon me. It is with pleasure that I am enabled to lay before the Society the results of my investigation in this direction.

Some short time since the Bureau of Agriculture for Western Australia, forwarded to the Technological Museum a sample of the kino of the Red Gum, *Eucalyptus calophylla*, R. Br., and in investigating this kino, which belongs to the turbid group of Eucalyptus kinos, it was found that the turbidity was caused by the second body found in the kino of *Eucalyptus hemiphloia* and named *Aromadendrin*. It was also found that "eudesmin" was entirely absent. This was a most gratifying discovery, as it has enabled me to make this investigation upon a pure substance, free from "eudesmin," the presence of which in a kino makes it exceeding difficult to obtain *Aromadendrin* sufficiently pure for research

[1] A Contribution to the Chemistry of Australian Myrtaceous Kinos—Journ. Royal Society of N. S. Wales, 1895, Vol. xxix., p. 30.

purposes, at all events with our present known methods of separation. Whether its insolubility in chloroform can be utilized to separate it successfully from "eudesmin," which body is readily soluble in that liquid, is a matter for further investigation.

Method of Preparation.

The fine powder of this kino was treated with a small quantity of water and placed in separator for the attempted determination of "eudesmin," as fully described under that substance, in the paper already referred to. The ether was more reddish-brown than was the case with the kino of *E. hemiphloia*, and when distilled to dryness did not deposit tufts of crystals as was the case in that of the latter kino under the same condition. When tested for the characteristic colour reactions of "eudesmin" it was found that that body was absent, and that apparently the whole consisted of *Aromadendrin*, giving the same colour reactions as that body before described. The residue after the ether had been distilled off was more difficult to crystallize out than "eudesmin," the solution requiring to be cooled considerably before it could be obtained in any quantity, and it also required to stand some hours when only the smallest possible quantity or absolute alcohol had been used for solution. When these crystals are filtered off, they cannot be washed with rectified spirit as they are readily soluble in that liquid, but may be washed once with absolute alcohol; or dried as much as possible on a porous slab, recrystallized from boiling absolute alcohol, dried again on the slab, and then crystallized twice from boiling water. When the substance is dissolved in boiling water, it becomes a jelly-like mass on cooling, the fine acicular crystals holding the water mechanically. The water is filtered off as much as possible, and the crystalline mass placed on a porous slab to dry. When thus prepared the substance is quite white and has the appearance of paper pulp, the interlaced hair-like crystals giving it a peculiar matted appearance, having a silky lustre, and totally distinct in physical appearance from "eudesmin." When these two bodies are prepared under like conditions they are both white, but "eudesmin" has the appear-

ance of small scales, and separates in particles, while *Aromadendrin* has the appearance of flakes of matted material. This difference in appearance is very marked.

Colour Reactions etc. of Aromadendrin.

When the dry substance is treated with concentrated sulphuric acid, the solution becomes of a fine yellow colour which fades and darkens on standing some time, thus differing entirely in this reaction from "eudesmin" which gives a purple colour under like conditions.

With nitric acid it gives a fine crimson colour, thus differing from "eudesmin" which gives a yellow colour with this reagent. Potash gives a fine yellow colour.

When dissolved in the smallest quantity of glacial acetic acid, and water added, nothing is precipitated, but after some time hair-like tufts of radiating crystals form. This is also a characteristic reaction differing from "eudesmin"; because, when "eudesmin" is dissolved in the smallest quantity of glacial acetic acid and water added, the first drop causes turbidity; if now enough water be added to cause the whole to remain turbid, beautiful crystals soon form, the turbidity disappearing and the whole becomes crystallized. This is an easy method whereby to obtain "eudesmin" crystallized in well shaped and fair sized crystals.

The melting point of *Aromadendrin* was found to be 216° C. (uncorrected) on the surface of mercury; the previous melting point was evidently taken on impure material, and not free from "eudesmin." Chloroform does not dissolve *Aromadendrin* but it readily dissolves "eudesmin."

If these reactions are tabulated the differences are brought out more distinctly:

	Eudesmin.	Aromadendrin.
H_2SO_4 (Concentrated)	Dissolves dark, after a short time becomes purple on edges and after half an hour beautiful purple liquid.	Dissolves yellow, becomes dark and fades on long standing. On heating becomes orange.

	Eudesmin.	Aromadendrin.
HNO_3 (Fuming and ordinary)	Dissolves yellow, after some time dendritic forms appear and continue to increase, being yellow in colour.	Dissolves with a fine crimson colour. (This reaction diminishes the value of this test for ellagic acid.)
KHO	Little change.	Dissolves a fine yellow colour which remains persistent.
Glacial Acetic Acid	Dissolves; on addition of small quantity of water becomes turbid, crystals soon form, turbidity is removed and the whole becomes crystallized.	Dissolves; on addition of water does not become turbid, even when more than an equal quantity of water has been added. Hair-like tufts of crystals form on standing.
Melting Point	99° C. on the surface of mercury. The same in water in fine tube sealed at end.	216° C. (uncorrected) on the surface of mercury. Closed tube determination not satisfactory.
Heated between watch glasses	Melts at a low temperature to a clear liquid, and on continued heating chars but slightly, a whitish resinous mass being left.	Melts at high temperature and commences to darken at once, very quickly beginning to char.
Chloroform	Readily soluble.	Almost insoluble.
Chemical Formula	$C_{28}H_{30}O_8$	$C_{29}H_{26}O_{12}$ when heated to 120° C., or $C_{29}H_{26}O_{12} + 3\ H_2O$ when only air dried.

It may be well to direct attention to the danger of a mixed compound, when preparing these substances. The plates of the second body mentioned in the former paper evidently consisted of such, and contained enough "eudesmin" to alter the melting point as they gave a melting point of 162° C. Later a purer product of *Aromadendrin* was obtained from the kino of *E. hemiphloia* which melted at 192° C., while the melting point of pure *Aromadendrin* is 216° C.

Aromadendrin is readily soluble in ether, acetic ether, rectified spirit, and amyl alcohol; but is almost insoluble in chloroform. It is insoluble in benzole and petroleum spirit. When dissolved

in those solutions mentioned, the crystals left on evaporation all tend to form acicular radiating tufts; this is so when slowly crystallized from water, alcohol, dilute acetic acid, ether, and acetic ether, and it appears difficult to obtain crystals of fair size from any solution. The first crystals obtained from the solution in absolute alcohol, although impure, appear to be of larger size than by any other method.

Aromadendrin also gives the following reactions, the cold aqueous solution of the substance being taken for the determinations except as otherwise mentioned. The small amount of the substance in solution is not sufficient to redden litmus, although a stronger solution in hot water does so readily. With solution of acetate of lead a yellow-coloured precipitate is formed; in a stronger solution in hot water a dense precipitate forms of a yellow-chrome colour, becoming ochre-yellow on drying.

With solution of sulphate or acetate of copper a light greenish precipitate is formed; this is much more copious in a strong hot solution of the substance.

Acetate of zinc or acetate of cobalt, both fail to form a precipitate, the salts being soluble.

Gold chloride gives a purple colour, the dilute solution of gold being readily reduced.

Silver nitrate gives no precipitate but is reduced; this very readily takes place in a hot strong solution of the substance, a bright silver mirror being formed.

Ammonio-nitrate of silver is readily reduced.

Fehling's solution is also reduced on heating.

Gelatine gives no precipitate.

All akaline solutions give a yellow to orange colour, ranging from the light yellow given by lime-water, to the orange colour given by ammonia.

Ferric chloride gives a purplish-brown colour in all solutions, however dilute, there is not the slightest indication of a green colour, and it does not readily form a precipitate.

Ferric acetate gives a lighter purplish-brown and forms a precipitate.

Ferric chloride added to a portion of the dry substance gives a purplish-brown colour. With "eudesmin" this reagent only stains the crystals slightly yellow.

Composition of Aromadendrin.

Combustion was made of the substance after repeated crystallization from alcohol and water; it was perfectly white, had the characteristic felted appearance of this substance when crystallized from hot water; it gave the characteristic colour reactions perfectly, and melted on the surface of mercury at 216° C. The portion taken for combustion was previously heated in air-bath at 120° C. as the whole of the water is given off at that temperature, no further loss being experienced when melted. It was extremely light, the quantity taken filling the platinum boat.

No. 1 ·1550 gram. gave ·348 gram. CO_2
and ·0648 gram. H_2O
equal to 61·233 per cent. Carbon
4·645 „ Hydrogen
34·122 „ Oxygen

No. 2 ·1324 gram. gave ·2982 gram. CO_2
and ·0550 gram. H_2O
equal to 61·4252 per cent. Carbon
4·6156 „ Hydrogen
33·9592 „ Oxygen

Mean of the two combustions—

61·3291 Carbon
4·6303 Hydrogen
34·0406 Oxygen

From which we may deduce the formula—

$C_{29}H_{26}O_{12}$

Theory requires for this formula—

61·484 Carbon
4·593 Hydrogen
33·923 Oxygen

This agrees very well with the percentage amounts obtained by experiment.

Combustion made on material before heating to 120° C. was not satisfactory, the results of three combustions not being sufficiently constant It was found that 8·86 per cent. of water was removed by heating from 120° to 130° C. in air oven, while by heating in water bath until constant 6·1 per cent. was removed. Taking the formula as given above it is seen that it requires three molecules of water to equal 8·71 per cent., so that *Aromadendrin* crystallizes with three molecules of water ; two of these molecules are removed at or below 100° C., while the other is removed between that temperature and 120° C., the formula for this body is before heating therefore $C_{29}H_{23}O_{12} + 3\ H_2O$. The removal of these molecules of water does not form coloured anhydrides when not heated beyond 120° C. the substance remaining quite white. When heated to melting kino-yellow is formed.

Solubility of Aromadendrin in Cold Water.

A portion of the purified substance was dissolved in warm water and allowed to cool to 15·5° C., when the greater portion of the substance had crystallized out. This was filtered off, and a portion of the filtrate evaporated to dryness ; it was found that the residue equalled ·036 per cent. only, soluble in cold water at the temperature given, or that it required 2,777 parts of cold water of that temperature to dissolve one part of *Aromadrendrin.*

Several attempts were made to form salts, but owing to their instability, the results were not very satisfactory. The lead precipitate obtained by adding lead acetate to a hot strong solution appeared the most satisfactory. The lead precipitate thus obtained left 45 per cent. of PbO on ignition, this corresponds to half the

molecule, or the precipitate contained two atoms of lead in the molecule.

Although somewhat resembling catechin in many respects, such as melting point; not precipitating gelatine; reduction of gold and silver salts; its apparent action like an acid, although but slightly acid to litmus; its reaction with acetate of lead, &c.; its slight solubility in cold water; its crystallizing in needles with water; and a few other reactions; yet, it differs from catechin in its composition; its reaction with ferric chloride; its not forming pyrocatechin on heating in glycerol from 220° C. to 230° C. for half an hour; its different reactions with potash solution and sulphuric acid; and its not imparting brown tints to cotton cloth when boiled with solutions of sulphate of copper, and potassium bichromate, it having very little dyeing properties.

We must admit the family likeness however, and if we consider the composition of the members of the catechin group and the relations of the catechin tannins, we cannot but recognise the probability that eventually some connection will be found to exist between *Aromadendrin* and the tannins of the turbid group of Eucalyptus kinos.

The reactions of the products obtained by fusing *Aromadendrin* with caustic potash, indicate that both phloroglucol and protocatechuic acid are formed.

Kinoin from Malabar kino is a body also allied in some respects to catechin, and in some of its reactions to aromadendrin.

When *Aromadendrin* has been heated in glycerol, the ether removes a yellow resinous looking body which is almost insoluble in cold water, but instantly soluble in alcohol, forming a yellow solution of great staining power, dying the skin, wool, etc., a bright yellow. This is an alteration product that may be considered as *kino-yellow*, and is worthy of further investigation. Kino-yellow is also obtained when *Aromadendrin* is heated above its melting point.

Aromadendrin is almost tasteless, being perhaps slightly sweetish. It has no odour.

Although the term aromadendric acid has been used for this substance, it should only be so considered in the sense already adopted for catechuic acid, as the acid qualities of the former are but slightly greater than are those of the latter, but it may eventually be proved to form one of a series of the tannic acids of the Eucalypts, and may probably be a starting point for those as yet but little investigated bodies.

The ready isolation and determination of these two bodies eudesmin and aromadendrin, will assist in the elucidation of many problems connected with the large group of Eucalyptus kinos known as the "Turbid Group," and will enable it to be broken down on a purely scientific basis, a result long hoped for. Much work will require to be done before an authentic scheme can be laid down, but from our present knowledge, I look forward to an easy, accurate, and scientific method of arranging the members of this large group in their proper classes, and to eventually settle, chemically, the affinities existing between the Eucalypts, and thus help to bridge over the difficulties which have up to the present existed in reference to the members of this important genus.

We require now a method whereby these bodies can be correctly separated, both from each other and from the tannin of the kino, and until this mode of procedure is worked out, it is little use attempting a gravimetric determination of the original kinos.

ON THE CELLULAR KITE.

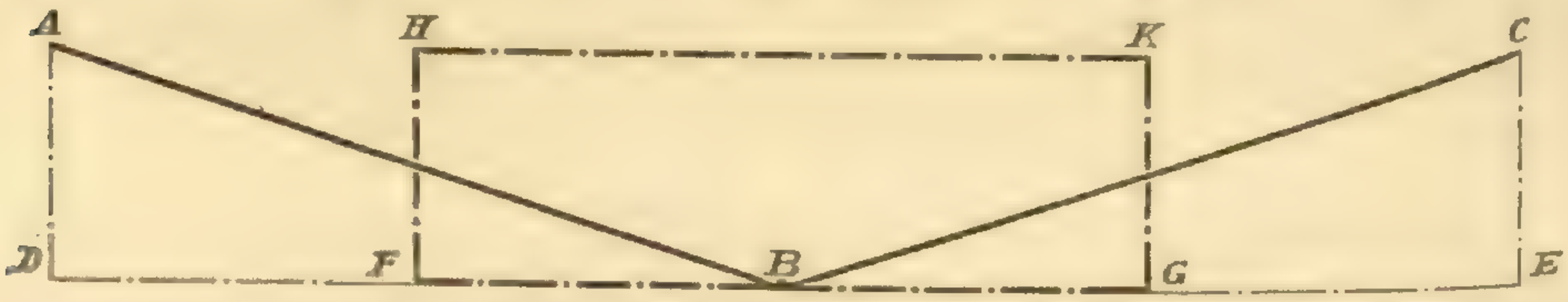
By Lawrence Hargrave.

[With Plate VII.]

[*Read before the Royal Society of N. S. Wales, August 5, 1896.*]

As there is little doubt that the cellular is a permanent type of kite, a few remarks will be of interest; especially as its action and construction as hitherto explained are somewhat obscure. The first question that suggests itself, is, why should the cellular lift more per square foot than the ordinary single surfaced kite? In a kite or flying machine the distribution of the lifting surface is most important. The value of the lifting surface depends within certain limits on the linear dimension that first meets the wind. Thus, a common kite of twenty-five square feet area cannot show more than about seven feet of edge to the wind, whereas a cellular one of twenty-five square feet area can easily show twenty feet of edge to the wind.

The great stability of the cellular kite is due to the vertical surfaces. To understand this, it is necessary to grasp the truth, that a perfectly flat kite has no stability; and even with tail and side ropes is an inferior flyer. The more the kite bends back from the longitudinal centre line or back bone, the more stable it becomes. The angle between the two sides is called by flying-machine men the diedral angle, and without this or its equivalent, no flying apparatus will balance with any degree of certainty.



Let A B C be the diedral angle of a kite. B being the end view of the back bone. Resolve A B and B C into their components, and D B E is the breadth of surface that tends to lift

the kite, and A D and C E are the heights of the surfaces that tend to steady it. Bisect D B and B E, and erect perpendiculars F H and G K equal to A D or C E, join H K; and F H K G is the breadth and height of a cell having the same lifting power as A B C and (apparently) greater stability.

The width of the kite D E is halved, and therefore much less timbering spreads an equal area of lifting surface to say nothing of the rigidity of the lattice girder construction.

To realize this question of stability from another point of view, let us imagine a flying machine with its lifting surfaces in the diedral fashion A B C, and one with two cells like F H K G, to be on their respective stages, rails, carriages or floats, ready to fly: suppose them to have equal areas, weights and wheel or other bases and to be heading directly to the wind; a momentary change of wind would promptly overturn A B C, but F H K G would only be pushed sideways.

Suppose both machines to be flying at the same speed and to require to turn to the right suddenly. They each port their helm with the result that the diedral one turns on its beam ends to starboard and the cellular one loses way due to the amount of vertical surface and develops a slight listing moment to starboard.

A comparison of the scale drawing of a ninety square feet kite (*Plate* 7) with *Plate* 8 of the paper on "Aeronautical Work" read here on June 5th, 1895, will show detail improvements that have lately been made. The 1895 drawing shows the main frame to have had three king-posts and four diagonal wire ties, these are now abolished and the cells brought closer together longitudinally. The frame now consists of two pieces of wood, each three times the length of the cell, united by the ties (B) at the centres of each cell. The effect of this alteration is that the kite is equally strong with less material, and it will fold to a close bundle seven feet six inches long, with a maximum circumference of sixteen inches. This makes the question of transport a very simple matter.

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The strop for the kite line (D) and that for any kites that may be flown above (A), pull on to the tie of the forward cell, so that no special rigging is required for tandem flying.

The fabric of the surfaces can be adjusted easily to any degree of tension by the ties (B): previously it required some effort to fleet the boom shoes along the main frame.

The booms (C) for pushing out the jackyards (E) are of plano-convex section instead of being round; this adds a little to their weight, but something is gained by the reduced head resistance, and the lift due to the plane underside of the booms.

The booms for the lower corners are continuous, those for the upper corners are joined at the crossings by tape or string hinges to the continuous booms, this brings all compressions of the truss work of each cell into one plane.

The outer ends of all the booms have wooden cleats (R) lashed on top and bottom, so that the jackyards (E) fitting exactly between them, receive the thrust truly square. The inner ends of all the booms are quite square and rest in beds on the main frame. There are no metal ferrules, joints, nails, or shoes on the kite.

The sticks for bending the surfaces (F) have a versed sine of 1·125 inches. They are not steamed, or held bent by a cord or wire. They are simply made in two or three layers of wood united with glue. The sticks retain the form given them and acquire an extra stiffness due to the glue.

The total weight of this ninety square feet kite is twelve and a half pounds; at least a pound of this might be saved by using light muslin instead of calico.

The lifting power at the ultimate strength of the structure is not known; it is estimated to be about three pounds per square foot, and that a wind of thirty miles per hour would not break it, or make it dive. This kite was flown on July 22nd, at 2 p.m. You will remember the weather as reported in the *Sydney Morning Herald* next day. One of the jackyards broke at a small nail hole, and one pair of booms fell to the ground, but the kite con-

tinued to fly steadily. It is this remarkable stability that makes the cellular form of aeroplane so suitable for flying-machines, and it is a matter of surprise to the writer that other experimenters do not adopt it, especially as there is no charge for its use.

For man lifting purposes, small kites are better than large ones. For instance, a nineteen square feet kite has been made that weighs nineteen ounces, and folds to about the size of an umbrella; ten of these could be tucked under one's arm, and with a coil of line and a decent breeze an ascent could be made from the bridge of a torpedo boat or the top of an omnibus.

Some confusion has arisen through the apparent ambiguity of the definitions of the dimensions of cellular kites. They fly at such a high angle and present such a small projected area to the wind, that when viewed from below, misunderstanding cannot ensue if:—

Length equals the dimension in the direction the wind is blowing.

Breadth equals the dimension horizontally at right angles to the length.

Depth equals the dimension vertically at right angles to the length.

NOTE ON A METHOD OF SEPARATING COLLOIDS FROM CRYSTALLOIDS BY FILTRATION.

By C. J. MARTIN, D.Sc., M.B., Demonstrator of Physiology in the University of Sydney.

(From the Physiological Laboratory of the University.)

[*Read before the Royal Society of N. S. Wales, August 5, 1896.*]

THE method consists in filtering under a pressure of forty to fifty atmospheres, through a film of gelatin or gelatinous silicic acid. In order to do this the film must be supported at frequent intervals.

This is accomplished by using the candle of a Pasteur-Chamberland filter as the scaffolding to hold the gelatin.

The apparatus consists of—

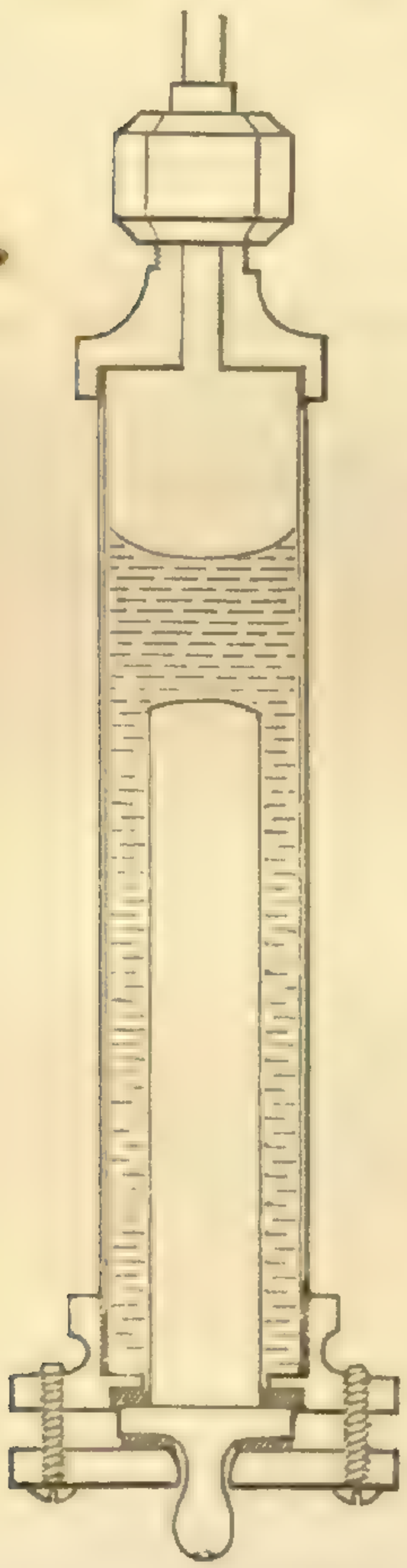
(1) A steel cylinder containing compressed air.

(2) A pressure gauge, T junction, and connections of copper piping.

(3) A gun-metal case to hold the filter, tinned inside.

(4) A Pasteur-Chamberland filter, the pores of which have been filled with gelatin or gelatinous silica.

The filters are securely fixed into the case by pressing the flange on them tightly against a rubber washer resting upon a small platform in the end of the filter case. On the outer surface of the flange is another rubber washer and then a disk of metal with a central aperture to allow the spout of the filter to project. This disk has five holes near its circumference through which screws pass to be inserted into a projecting rim on the end of the filter case. When these are screwed home the flange is compressed between the washers and forms a tight joint. (Vide figure in text).



A membrane of gelatin in the pores of the filter is produced, by first filtering a hot 10% solution of gelatin through them, allowing the gelatin to set and subsequently washing the excess from the outside and inside of the filter with hot water. A membrane of silicic acid is made by first sucking a solution of sodium silicate through the filter and afterwards converting this into gelatinous silica by immersing the filter in 2% hydrochloric acid for a couple of days.

Either film entirely prevents the following substances from passing through :

Proteids ...	...	Albumens Globulins Fibrinogen Nucleo-albumens Hæmoglobin Caseinogen
Carbohydrates	...	Glycogen Soluble starch (Amyl.-dextrin)
Colouring Matters		Hæmatin Serum pigment Egg-white pigment

Albumoses and peptones pass through the filter. Crystalloids pass through and *at the same rate as water*, for a solution of glucose or salt neither gains nor loses in concentration by filtration.

The method I have found of service in some physiological enquiries. If blood is placed outside the filter, the solution coming through is rid of all albuminous and colouring bodies. It is clear, colourless, and contains the glucose salts, urea etc., in a condition favourable for quantitative analysis.

For solutions of crystalloids I believe the process to be one of true filtration and in no way connected with the phenomena of molecular diffusion. The molecules of albumen and other proteids are unable, probably on account of their size, to pass through the pores of the jelly.

AN EXPLANATION OF THE MARKED DIFFERENCE IN THE EFFECTS PRODUCED BY SUBCUTANEOUS AND INTRAVENOUS INJECTION OF THE VENOM OF AUSTRALIAN SNAKES.

By C. J. MARTIN, D.Sc., M.B., Demonstrator of Physiology in the University of Sydney.

(From the Physiological Laboratory of the University.)

[*Read before the Royal Society of N. S. Wales, August 5, 1896.*]

IN a recent paper on the physiological action of the venom of *Pseudechis porphyriacus*,[1] I drew attention to the fact that the results following subcutaneous and intravenous inoculation were frequently so different that one could hardly imagine one was dealing with the same poison. Speaking very generally, when minimal fatal doses were employed, after subcutaneous inoculation, death occurred through paralysis of the respiratory centre, whereas in those experiments in which the venom was introduced directly into the circulation, death was brought about by the destructive operation of the venom upon the blood corpuscles, setting free nucleo-albumens which occasioned thrombosis.

This difference is such, that two observers who experimented, the one with intravascular the other with subcutaneous injections, would assuredly arrive at quite different conclusions as regards the physiological action of this snake venom. This variation in symptoms according to the method of introduction of the venom is not however confined to observations made with the poison of Australian snakes. The work of most experimenters on snake poisons exhibits the same fact, and this extraordinary variation in results has given rise to much confusion.

These differences, as I have shown in the paper referred to, are to a large extent dependent upon the varying rapidity with which

[1] Proc. Roy. Soc. N. S. Wales, 1895.

the poison reaches the blood, and I think I am now in a position to completely elucidate the matter.

With this object it is necessary to consider for a moment the chemical constitution of snake venoms. Venoms are solutions of proteids, together with a trace of inorganic salts and a small quantity of an organic acid and colouring matter. All venoms so far investigated contain at least two kinds of proteids, one of which is precipitated by heating the solution. The relative amounts of these two proteids are not constant in venoms from different species of snakes. Weir Mitchell and Reichert[1] found that the proportion of coagulable to total proteid in the poisons of these different kinds of snake was—

Crotalus ...	25%
Ancistrodon ...	8%
Cobra	1·75%

The physiological action of these three venoms varies very greatly, and in the same order as their content of coagulable proteid. *Crotalus* venom produces the greatest destruction of cells generally, *e.g.*, blood corpuscles, epithelium of vessels, and epithelium of kidney. *Ancistrodon* venom operates on these elements less than *Crotalus* poison but much more than that of *Cobra.* The poison of the *Cobra* exercises comparatively little effect on tissues generally, but confines its action principally to nerve cells, and those nerve cells constituting the respiratory centre in particular. A further interesting observation by these authors, is, that after heating, *Crotalus* or *Ancistrodon* venom to 80° C., by which means the coagulable proteid is separated in an insoluble form, these venoms no longer produce their destructive effect on blood and tissues, but now kill by paralysis of the respiratory centre, as is the case with *Cobra* posion.

Pseudechis poison when injected into dogs, produces wholesale destruction of blood corpuscles the products of their destruction causing thrombosis. When however, this venom is previously

[1] Smithsonian Contributions to Knowledge, Vol. XXVI.

heated to 85° C. it only possesses this power to a trifling extent, and to compass the death of the animal by intravascular clotting, the dose must be increased five-hundred fold.

An obvious inference from these facts is that the body in venoms which destroys blood cells and kidney epithelium is the proteid coagulated by heat.

It must however be borne in mind that heat affects venoms in two ways :—

(1) By coagulating some of the proteids present, in which condition they are inert.

(2) By imparing the toxic power of the proteids present without influencing their solubilities, or indeed changing them in any way recognisable by chemical tests.

The first method of action is sudden. When the solution is raised to a certain temperature some portion of the proteid constituents is coagulated.

The second method is gradual, the longer the heating and the greater the dilution of the solution the more impairment of virulence occurs. Perfectly dry venoms may be submitted to a temperature above 100° C. without diminishing their toxic power. *Cobra* poison is least affected by heating, whereas viperine poisons are very sensitive to heat when in solution.

Accordingly, before I could conclude that the alteration in the action of *Pseudechis* venom was due to the exclusion of one of the poisonous constituents by heat, it was necessary to accomplish the separation by some other means which should not at the same time modify the remaining constituent. This I have been able to do, and by a method which has thrown light upon the causation of those differences in effects which follow subcutaneous or intravenous inoculation. The method consists in filtering a solution of venom through a film of gelatin by aid of a hydrostatic pressure of fifty atmospheres.[1] The proteid which is coagulated by heat

[1] C. J. Martin—"Note on a method of separating Colloids from Crystalloids by Filtration.—Proc. Roy. Soc. N. S. Wales, 1896 and Journ. of Physiol. 1896.

does not pass through the filter, whereas the other proteid does. The filtrate is still highly poisonous, but a whole group of symptoms which are characteristic of the venom, are absent, as was found to be the case after heating to 82° C.

This fact is illustrated by the following six experiments:—

Experiment 1—0·05 gramme of *Pseudechis* venom was dissolved in 50 cc. of 0·9% NaCl solution. 10 cc. were kept for comparative experiment, and 40 cc. passed through the filter.

10 cc. of the filtered and 10 cc. of the unfiltered solution of venom were both faintly acidified and boiled. The unfiltered solution of venom gave cloudiness which settled as a precipitate; the filtered venom remained absolutely bright and clear. Filtering through gelatin had kept back the coagulable proteid.

I then tried whether the filtration had also deprived the venom of its capacity of destroying dogs' red blood corpuscles *in vitro*.

Experiment 2—Four slides were prepared. On two a drop of blood from a dog was mixed with an equal volume of 0·9% NaCl solution. On two others a drop of blood was mixed with a drop of the solution of filtered venom.[1] All four slides were ringed round with acid-free oil to avoid concentration, and left at the laboratory temperature 12° C. By next day (twenty-four hours) no difference was to be observed between the venom slides and the control slides.

Experiment 3—Four other slides were prepared as before, two with isotonic salt solution alone, and two with the same salt solution containing 0·01% venom. In this experiment the slides were kept at 37° C. Next day no difference could be detected between the four slides.

As under the same circumstances a similar solution of unfiltered venom would have broken up the majority of the corpuscles, I conclude that the active agent in this regard is separated by filtration through gelatin.

[1] This was a 0·9% NaCl solution containing 0·1% of venom.

I then injected the remaining portion of the filtered venom solution into a dog to see whether the usual destruction of blood corpuscles, hæmorrhages, and affection of the kidney would be absent.

Experiment 4—Small dog, weight 4 kilogrammes.

July 14, 11 a.m.—9cc. of 0·1% solution of *Pseudechis* venom previously filtered through gelatin injected into each flank. (Amount injected equal 0·018 gramme). Temperature 39° C.

„ 11·25 a.m.—Vomited, tremulous, uncomfortable.

„ 3·15 p.m.—Very "tucked up," lethargic, weak on hind legs. Temperature 32° C.

„ 4·30 p.m.—Passed loose fœtid mucous stools but no blood. Can just walk, sinks on haunches. Respiration a little stertorous. Has passed no urine; Temp. 38·9° C.

„ 6·30 p.m.—Condition a little worse. Temperature 38·8° C. No urine passed.

July 15, 9 a.m.—Cannot stand. Has eaten two biscuits during night, but vomited them. Respiration very noisy; temperature 38° C. Passed a small quantity of highly concentrated urine containing no albumen or blood pigment; pupils dilated.

„ 12·30 a.m.—Condition the same; drop of blood taken from the ear. Appearance normal, except large increase in leucocytes. No hæmoglobin in plasma.

July 16, 9 a.m.—Quite lively, runs about and takes food well. No trace of weakness in limbs. Little urine passed in capsule, very concentrated, otherwise normal.

Experiment 5—Small dog, weight 5½ kilogrammes.

July 16, 10 a.m.—10cc. of a 0·2% solution of venom which had been filtered through a gelatin film, injected under skin of back. Temperature 39° C.

July 16, 11 a.m.—Has vomited; tucked up appearance.
,, 2 p.m.—Has passed loose stools but no blood; lethargic, weak on legs. Temperature 38·6° C.
,, 4 p.m.—Cannot walk. Breathing laboured and noisy (laryngeal). Temperature 38·5° C.
,, 6 p.m.—Cannot stand. Breathing slow and laboured. Has passed a small quantity of urine containing no albumen or blood; pupils dilated. Temperature 38·3° C.
Next day, 9 a.m.—Found dead. P.M.—Slight extravasation at seat of inoculation. Blood partially clotted in heart, fluid elsewhere. Examination of blood showed no destruction of corpuscles. A little urine in bladder, *not* albuminous. No hæmorrhages in any of the organs. Kidneys congested but otherwise normal.

All these experiments are characterised by the absence of the usual destructive effects on corpuscles, and kidney complications, which I have always noticed with the entire venom when dogs have been the animals experimented with. They agree however, absolutely with other experiments in which venom previously heated to 85° C. was injected.

Experiment 6—The same dog which was injected with filtered venom ten days previously but recovered. During the interval he had been in good health and gained weight. Present weight 4·25 kilogrammes.

July 24, 9 a.m.—0·018 gramme of the entire venom injected under skin of back. Rectal temperature 39° C.
,, 11·10 a.m.—Has vomited. Nearly dead; heart beats very slow and irregular (twenty-four per minute). Pupils dilated; corneal reflex just present. Respiration occasional.
,, 11·15 a.m.—Dead. P.M. examination made directly—Small fibrinous clot in right ventricle. Vena cava contained fluid blood, which clotted instantly

on being drawn. Portal, splenic, mesenteric, and renal veins thrombosed. No urine in bladder. Examination of blood—Hæmoglobin in solution in the plasma. Extensive extravasation of blood in situation of inoculation. Hæmorrhages in lungs and portal area.

In this experiment the amount of poison injected was the same as formerly (Experiment 4). In this case however, the entire venom was introduced and the animal speedily succumbed from extensive intravascular clotting, whereas in the previous experiment he nearly died from respiratory paralysis, but ultimately made a speedy recovery. In the first experiment there were no symptoms indicating destruction of blood corpuscles, or hæmorrhages, whereas the post mortem following Experiment 6 demonstrated that both had occurred.

I therefore conclude that *Pseudechis* venom contains at least two toxic proteids :

(1) A proteid precipitated on heating the solution to 82° C. and indiffusible.

(2) An albumose,[1] not precipitated by heat and diffusible.

(3) And that the former is responsible for the destruction of blood corpuscles and hæmorrhages, whereas the latter is principally a nerve-cell poison and is endowed with a selective affinity for those nerve-cells constituting the respiratory centre.

If two poisons, one of which passes much more readily through the capillary wall than the other, be simultaneously injected into a connective tissue space, the former will reach the circulation more rapidly than the latter. Under such conditions the effect

[1] It is difficult to classify this proteid in any present system. It is not rendered insoluble in dilute saline solutions by prolonged sojourn under absolute alcohol. This fact would point to its being an albumose. Its inability to pass through a film of gelatin, and coagulation on heating, would lead one to class it with the abumens or globulins.

produced may be largely that of the diffusible poison, at any rate until after the lapse of some interval of time. If the more rapidly absorbed constituent be a powerful poison, the animal may succumb to its effects before the less diffusible constituent has reached the circulation in sufficient concentration to occasion any marked effect. On the other hand if the quantity of the former is sub-lethal the animal may suffer from its effects, recover, and subsequently exhibit all the symptoms due to the latter.

When, however, the mixture of poisons is directly introduced into the blood stream, both poisons produce their individual effects simultaneously, and the animal may succumb to one or other, according to the relative amount of each present, and to the varying sensitiveness of some essential portion of the physiological mechanism.

When a minimal lethal dose of venom is subcutaneously injected the symptoms may be confined to those occasioned by the diffusible constituent. The reason is that the indiffusible proteid has been absorbed so slowly that the animal has succumbed to the influence of the diffusible constituent, or else that the absorption of the former was so slow that it was eliminated as rapidly as absorbed. Also, it has not infrequently happened that an animal has recovered from the paralytic symptoms, been apparently well for some hours, and afterwards died from extensive hæmorrhagic pneumonia, due to multiple thrombi in the pulmonary circulation, or other grave results secondary to blood cell destruction.

The records of some cases of snake poisoning in Australia show a complete parallelism with these experimental results. It has happened that the patient has recovered from the paralytic symptoms, and has been to all appearance out of danger for a considerable number of hours, but has succumbed in one or two days with symptoms of extensive blood-cell destruction such as hæmoglobinuria together with evidence of serious kidney mischief.

On the OCCURRENCE of a SUBMERGED FOREST, with REMAINS of the DUGONG, at SHEA'S CREEK, NEAR SYDNEY.

By R. Etheridge, Junr., Professor T. W. Edgeworth David, B.A., F.G.S., and J. W. Grimshaw, M. Inst. C.E.,

[With Plates VIII. – XI.]

[*Read before the Royal Society of N. S. Wales, August 5, 1896.*]

Contents:

I.—References by previous observers to movements of the East Australian Coast. (1) Submergence. (2) Elevation. (3) Stability.

II.—Shea's Creek. (1) The locality as it was before the Canal was commenced. (2) General Geological Features. (3) Details of the Section exposed in the Canal. (4) Description of the remains of the Dugong. (5) Traces of Man's Presence. (6) Description of the Submerged Forest.

III.—Deductions. (1) As to the evidence of Subsidence. (2) As to the geological antiquity of man in Australia.

I.—References by Previous Observers to Movements of the Australian Coast.

Evidence proves that changes have taken place, in comparatively recent geological time, between the relative levels of land and sea on the East Coast of Australia. The evidences may be divided into two classes, according as they show (*a*) a negative movement (subsidence) of the land or corresponding positive movement of the sea, as the case may be—[For this the term submergence will be used in this paper]—(*b*) a positive movement (elevation) of the land, or a corresponding negative movement of the sea.

(1) *Submergence.*—As this paper relates to submergence, evidences of submergence may be taken first. Darwin was in favour of the view that the Great Barrier Reef of Australia was evidence of submergence, though he does not supply many details.[1]

[1] Journal of Researches, 2nd Edit., 1845, p. 474.

He states in a later publication[1]:—"If instead of an island, as in the diagram, the shore of a continent fringed by a reef were to subside, a great barrier-reef like that on the north-east coast of Australia, would be the necessary result; and it would be separated from the main land by a deep-water channel, broad in proportion to the amount of subsidence, and to the less or greater inclination of the bed of the sea."

Prof. J. D. Dana and Commodore Charles Wilkes, U.S.N., were also of opinion that the Barrier Reef of Australia was evidence of subsidence. They state[2]:—"The coral reefs indicate an extensive subsidence along the east and north-east coasts of New Holland." On the following page they estimate the subsidence as not less than five hundred feet. On the same page is also adduced some evidence of elevation—"On the eastern coast there are occasional elevated beaches or deposits of shell and some appearances of terraces." Prof Dana dwells specially on evidence of a raised beach on the Illawarra Coast of N. S. Wales, between Bulli and Wollongong, about ten feet above sea-level. The fact, however, should here be mentioned, that subsequent researches show that this ridge is rather a storm-beach with midden remains than a true raised beach. Professor Dana in a later publication[3] repeated his statement, that the existence of barrier reefs on a coast is evidence of subsidence.

The Rev. W. B. Clarke was of opinion that a subsidence had taken place along the east coast of Australia, as proved by the following statement[4]:—"Whilst marine deposits of Tertiary age are found along the west coast of Australia, and along the southern coast from Cape Leeuwin to Cape Howe, there are no known *marine* Tertiaries in any part of the coast of New South Wales and Queensland up to the Cape York Peninsula; and the reason of

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[1] Structure and Distribution of Coral Reefs, 2nd Edit. 1874, p. 135.

[2] U. S. Exploring Expedition, 1838–42, Vol. x., Geology, 1849, p. 533.

[3] Corals and Coral Islands.—J. D. Dana, 1872, p. 319.

[4] Remarks on the Sedimentary Formations of New South Wales. By the Rev. W. B. Clarke, p. 7, 4th edit. By Authority, Sydney, 1878.

this may be, that, as indicated by phenomena before pointed out by me, but which on this occasion cannot be further dwelt upon, the eastern extension of Australia has been probably cut off by a general sinking, in accordance with the general Barrier Reef theory of Mr. Darwin."

Perhaps the most important statement on this subject is that made by Mr. C. S. Wilkinson, the late Government Geologist of New South Wales. He says,[1] with reference to Port Hacking, near Sydney :—"It will thus be seen that this locality is over a very deep portion of the coal basin. The eastern portion of this basin has been apparently faulted and thrown down beneath the waters of the Pacific Ocean, the precipitous coast, and a line about twenty miles east from it, marking approximately the lines of dislocation. The deep soundings immediately beyond this would seem to favour this view, so that here the bed of the ocean probably consists of the old land surface which once formed the continuation of that upon which the City of Sydney now stands, and which has been faulted to a depth of over 12,000 feet ; the length of the faulted area is not known, but it probably does not extend along the coast beyond, if so far as, the north and south limits of the Colony."

"The abrupt eastern margin of the Blue Mountains, up which the Great Western Railway ascends at Lapstone Hill, near Emu Plains, marks the site of a similar though not so extensive fault, by which all the country between it and the coast was thrown down to its present level—the depression being so great that the ocean water flowed into the old river valleys, one of which forms the beautiful harbour of Port Jackson. We have evidence that these faultings probably took place towards the close of the Tertiary epoch ; for no marine Tertiary deposits are known along this portion of the coast of Australia, whereas in New Guinea on the north, and in Victoria on the south, the marine Miocene beds occur at elevations up to eight hundred feet above the sea. Had

[1] Mineral Products of New South Wales etc., p. 52. By Authority, Sydney, 1882.

this low lying country along the east coast of Australia then existed, it must have been covered by the Miocene Sea, and doubtless some portions of the Miocene strata of that period would have escaped denudation, and have remained as those have which are seen in Victoria and elsewhere; but it is very probable that until or during the Pliocene period it stood at a much higher level and extended some distance beyond the present coast line. Then again the Tertiary deposits throughout east Australia show that the valleys draining the Great Dividing Range have been chiefly eroded since the Miocene period, for we find deep valleys and ravines cutting through later Tertiary formations; therefore, the sinking of the land traversed by any of these valleys, such as that of Port Jackson, evidently took place in comparatively recent geological times, and may have been contemporaneous with the extensive volcanic eruptions of the Upper Pliocene Period during which the southern portion of Victoria especially was the *locale* of great volcanic activity."

In 1886, Mr. Walter Howchin, F.G.S.,[1] recorded evidence of a supposed land surface submerged about twenty-six feet below sea-level, (high water) at Glanville, near Adelaide. The evidence is in the form of a crust of travertine capped by brown clay. In the absence, however, of land fossils, the evidence, as the author points out, is inconclusive.

Reference has been made by one of the authors to the occurrence of black loam and peat extending from about sixteen feet to thirty-six feet below low water at Narrabeen lagoon, about nine miles northerly from Sydney.[2] This is probable though not conclusive evidence as to submergence, as the peaty loam may possibly have been originally deposited below sea-level. Further evidence as to submergence along the eastern coast of Australia has been quoted by the same author in his Presidential Address for 1896 to this Society.

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[1] Trans. Roy. Soc., South Australia, Vol. IX., 1886-7, pp. 31 – 35.

[2] Annual Report Department of Mines, 1890, p. 236. Report by T. W. E. David. By Authority, Sydney, 1891.

(2) *Elevation of Coast* (or negative movement of ocean).—References to papers on the above subject have already been given by two of the authors elsewhere.[1] A brief summary will here suffice. Reference has already been made to the supposed raised beaches of the Illawarra District of New South Wales, noticed by Professor Dana during the United States Exploring Expedition under Commodore C. Wilkes, U.S.N., 1838 – 42.

In 1846, Captain Stokes quoted evidence of elevation near Cape Upstart, in the following words[2]:—"I will, myself, here adduce what may be deemed an important fact; and which, if allowed its due weight, will go far to weaken the arguments brought forward in favour of subsidence of the north-east coast of Australia. I found a flat nearly a quarter of a mile broad, in a great sheltered cove, within the Cape, thickly strewn with dead coral and shells, forming, in fact, a perfect bed of them—a raised beach of twelve feet above high water mark. . . . . Had it been on the seaward side of the Cape, I might have been readier to imagine that it could have been thrown up by the sea in its ordinary action, or when suddenly disturbed by an earthquake wave, but as the contrary is the case, it seemed impossible to come to any other conclusion than that an upheaval had taken place."

In 1847, Professor J. B. Jukes described small sandy flats of coral conglomerate, never extending more than fifteen feet above high water mark, at intervals along the north-east coast of Australia.[3]

In 1859, Mr. Ludwig Becker adduced evidence to show a rising of the shores of Hobson's Bay, Port Phillip, as shown by the readings taken by Mr. R. L. J. Ellery on the tide gauge at Williamstown near Melbourne.[4] Mr. Becker estimated the rise of the coast near Melbourne at four inches a year.

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1 Rec. Geol. Sur. N. S. Wales, Vol. II., pt. i., 1890.—Raised Beaches of the Hunter River Delta. By T. W. Edgeworth David and R. Etheridge Junr.. pp. 37 – 52, pl. 3. By Authority, Sydney.

2 Discoveries in Australia, etc., 1846, I., p. 332

3 Narrative of the Surveying Voyage of H.M.S. "Fly," 1847, I., p. 58.

4 Some facts determining the rate of upheaval of the South Coast of the Australian Continent.—Trans. Phil. Inst., Vict. 1859, III., p. 7.

In 1862, the Rev. J. E. Tenison-Woods corroborated Mr. Becker's observations, as to a rising of the southern coast of Australia, and on the evidence partly of the shallowing of the soundings, since they were taken by Flinders in 1802, partly from the occurrence of marine shells on the shores of coastal lakes now fresh, but evidently formerly salt, concluded that the rising affected the whole coast from Melbourne to King George's Sound.[1]

In 1869, Dr. Alexander Rattray published his opinion that in the Cape York district there was evidence of a recent elevation of the coast. He says[2]:—"Equally interesting is the evidence that the north-east, if not the whole of the east coast of Australia, is slowly rising, to be found in the gradual shoaling of the channel between Hinchinbrook Island and the mainland, (Lat. 18½° S.) which is due to all appearance, neither to silting up nor to the growth of coral—in the presence of waterworn caves in the sandstone cliffs of Albany Island and those of the mainland opposite, now well above high water mark—and in the existence along many parts of the coast, especially towards the northern end of the peninsula, of extensive tracts of level country now covered with sand dunes bearing a scanty vegetation stretching inland, and on either side to the base of lofty hills now ten, fifteen, or twenty miles off, but which had once closely bordered the sea, the whole looking as if they had once been under water."

In 1890 two of the authors published an account of some well developed and extensive raised beaches near the apex of the Hunter River Delta near Maitland, N. S. Wales. The marine shell beds nowhere attained a greater elevation than that of fifteen feet above high water.[3]

In 1892, Mr. E. J. Statham, Assoc. M. Inst. C.E., described certain shell heaps and shell beds near the mouths of the Clarence, Richmond and Brunswick Rivers.[4] He states,[5] "These layers are to

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[1] Geological Observations in South Australia, 1862, p. 205.

[2] Q.J.G.S., Vol. xxv., 1869, p. 302. [3] *Op. cit.*, p. 46.

[2] Journ. Roy. Soc. N. S. Wales, Vol. xxvi., 1892, pp. 304–314. [3] *Op. cit.* p. 306.

be found at levels usually from four to ten feet above high water, and are important as indicating that the east and south coasts (if not the whole insular mass of Australia) are rising, further support to which conclusion is afforded by the fact of nearly all the streams and estuaries having bar entrances, which in some instances become entirely blocked up until a passage is opened by land floods."

In 1894, Mr. G. A. Stonier, F.G.S., described a raised terrace of auriferous black sand, six feet above ordinary high water mark, near the Evans River in the Lismore District, New South Wales.[1] The following year Mr. J. E. Carne, F.G.S., described similar terraces at a level of a few feet above high water, at Jerusalem Creek in the same district.[2] Mr. Carne, however, states:— "Whether the slight elevation of the surface of the black rock represents an elevation of the land or depression of the sea bed, or simply an accumulation of sand thrown up by stormy conditions, sufficient data are not yet to hand to enable a determination to be arrived at."

(3) *Stability.*—The paper by Mr. T. E. Rawlinson, C.E., on the coast line formation of the Western District of Victoria,[3] does not bring forward evidence either as to elevation or subsidence, but is rather in favour of stability in the *level* of the coast line in recent geological time. He says,[4] "The formation of the land and its three distinct coast lines as described indicate considerable changes of coast, and these changes must have occurred *since the upheaval of the land to its present level.*"—(The italics are ours). He concludes that the land has gained on the sea in southern Victoria in recent geological time, chiefly through accumulation of shell sand, and not through elevation of the sea floor. R. Daintree referring to the eastern coast of Queensland, states that "little

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[1] Annual Report Department of Mines, N. S. Wales, 1894, p. 130. By Authority, Sydney, 1895. [2] *Op. cit.*, p. 151, 1895, published 1896.

[3] Trans. and Proc. Roy. Soc. Vic. Vol. XIV., pp. 25 – 34, 1878. [4] *Op. cit.*, p. 31.

upheaval of this portion of Australia has taken place since the last volcanic disturbances terminated."[1]

From the evidence above quoted it is clear that in comparatively recent geological time there has been a relative change in the level of land and sea along the east and south coasts of Australia of about fifteen feet, and this amount of alteration seems so constant as to incline us to the opinion that it may be due, as so ably advocated by Suess in his classic work, "Das Antlitz der Erde," rather to a negative movement of the ocean than to a positive movement of the land. On the other hand, Darwin, Clarke, and Wilkinson, have brought forward arguments, to which we think much weight should be attached, to show that in late Tertiary, perhaps even in Post-Tertiary time, there has been a considerable submergence, perhaps due to subsidence of the lithosphere, along the east coast of Australia. In comparing the conflicting evidences as to submergence and elevation along the east coast of Australia, the fact which has been well emphasized by Suess should always be borne in mind, viz., that in case of oscillatory movements even when the positive movement has greatly preponderated, it is chiefly as a rule, the traces of the negative movement that survive.[2] Positive movement (of the ocean) submerges old beach lines and hides them from view, with a covering of sediment, whereas raised beach lines are exposed to view and are not easily obliterated.

II.—Shea's Creek.

(1) *The locality as it was before the Canal was commenced.*—Previous to the cutting of the present canal and the artificial raising of the level of the surrounding land, the area referred to in this paper was mostly a salt water swamp, through which crept the sluggish malodorous Shea's Creek. Shea's Creek rises to the east of Redfern in some low sandy hills, and can be traced thence for a distance of three and a half miles south-south-west, until its estuary joins that of Cook's River, half a mile below the Cook's

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[1] Quart. Journ. Geol. Soc., Vol. xxviii., 1872, p. 273.

[2] Das Antlitz der Erde, von Eduard Süess, Vol. ii., p. 691, 1888.

River Dam, and about half a mile north of the point where the estuary of that river enters Botany Bay. For the greater part of its course it was little more than a ditch, and was tidal for about a mile and a half above the point where it joined Cook's River. Its course throughout is almost entirely over alluvial deposits, derived from the denudation of the low hills of Triassic rocks (Wianamatta Shales and Hawkesbury Sandstone) which lie to the north-west, north, and north-east. It is the alluvial flats which lie on either side of the tidal portion of Shea's Creek, which constitute the salt swamps referred to above. The surface of the swamp is covered by rank grass and salsolaceous plants with a thin belt of swamp oak *(Casuarina)* along its western margin.

(2) *General Geological Conditions.*—A glance at the geological sketch map accompanying this paper (*Plate* 8) shows that these alluvials form a somewhat delta-shaped area, about three and a half miles long from its apex to its seaward termination, and four miles wide measured along the shores of Botany Bay. To the west of the present canal area, and at a distance of about half a mile at right angles to Shea's Creek, the alluvials are sharply bounded on the south-west by Hawkesbury Sandstone, and farther north-east by the Wianamatta Shales. Eastwards their boundary is lost under the hills of blown sand in the neighbourhood of the Waterloo and Botany swamps and Randwick. The excavations for the Shea's Creek canal prove that these alluvials occupy the site of what has once been a large indentation of Botany Bay.

(3) *The Section exposed at Shea's Creek.*—The portion of the Shea's Creek canal excavations, specially examined by us, extends from the dam five hundred and fifty feet, measured horizontally, above Rickety Street, as far as the site of a second dam to the north-east, a further distance of 2,150 feet. The bottom of the canal is being carried to a uniform depth of ten feet below low water, and is one hundred feet wide at the bottom, and two hundred feet wide at the top. The mean rise and fall of the tide is about five feet, so that at mean high tide there will be a depth of fifteen feet of water in the canal when filled. The

alluvials on either side have had their surface artificially raised with material excavated from the canal, as shown on the sections accompanying this paper, (*Plate* 9, fig. 1.) As the original level of the swamp was there at, or a trifle below, that of mean high water, and as the canal has been excavated to a depth of fifteen feet below mean high water, it follows that a section of that thickness (fifteen feet) is exposed to view in the banks, wherever they have been cut down to the full depth, and have not yet been concealed by the fascine work and stone pitching with which the sides of the canal are being lined, from three feet below low water to the top of the embankment.

The nature of the strata observed by us is shown on figs. 1 – 2, of *Plate* 9. (*a*) The uppermost stratum is a bed of sandy peat from nine inches to one foot in thickness, obviously of recent origin. (*b*) Next in descending order are layers of blown sand, with interstratified peaty partings, the whole having a thickness of about three feet. The outcrop of these beds is stained yellow and orange by a superficial film of sulphate of iron and alum. (*c*) A well marked horizon follows where marine shells are plentiful especially *Anomalocardia trapezia.* The bed was traced by us almost uninterruptedly from the dam above Rickety Street for nearly half a mile north-east. The shells are imbedded in sandy clay. A few varieties only, and all belonging to living species, are represented. The bed is two feet thick, and at its base is from one foot below mean low water to about two feet above. (*d*) A second layer of peaty loam passing in places into true peat with roots of various trees, and a few stumps of Swamp Mahogany underlies the shell bed just described.

On the longitudinal section the stump of a tree (No. 3 Stump) is shown on the horizon of this bed. *No. 3 Stump* was in pieces when seen by us. It was surrounded with sand containing partings of peaty matter, covered with a thin sandy clay. This stump was one foot seven inches above low water mark and possibly not *in situ.* The exterior showed traces of perforation by a boring amphipod, *Sphœroma verrucauda,* Dana. An allied species *S.*

quoyana, M. Edw., perforates sandstone rocks between tide marks; both are met with in Port Jackson. The stump belonged to the Swamp Mahogany, *Eucalyptus botryoides*, as determined by Mr. R. Baker of the Technical Museum. Near the preceding, we observed another stump, (No. 4) on the horizontal section.

Although the above stump was perhaps not *in situ*, numerous horizontal roots of trees were observed by us on this horizon, undoubtedly *in situ*, and the layer of peaty loam in which they occurred was very persistent. (*e*) Below the second well marked peat horizon is a bed of unctuous, plastic, dark bluish-grey clay, sandy in places, and occasionally showing vertical rootlets passing through it. The bottom of this bed rests, at about from nine to ten feet below low water, on the submerged forest, and a thick bed of peat, developed chiefly at the north-east end of the section. Marine shells are very plentifully and rather irregularly scattered through it, being most abundant near its upper surface, and, (towards the south-west end of the section) they form an irregular bed composed almost entirely of shells, and about two feet in thickness, extending from four to six feet below the level of low water.

On the east side of the cutting at position of No. 1 Stump, the bed is at least seven feet thick. The contained shells are strictly of an estuarine character, such as may now be met with in any of the muddy arms of the Parramatta River or sandy beaches connected therewith. A very similar bed of shells was excavated a few years back at Long Cove Creek, between Leichhardt and Dobroyd, Ashfield, the lithological character of the deposit being very similar to that of the present bed.

The organic remains so far obtained from this horizon, Shea's Creek, are as follows:—Annelida: *Polydora ciliata*, Johnston (borings). Echinodermata: *Salmacis Alexandri*, Bell. Pelecypoda: *Anomalocardia trapezia*, Deshayes; *Clementia papyracea*, Gray; *Tapes undulata*, Lam.; *Tapes turgida*, Lam.; *Tellina deltoidalis*, Lam.; *Tellina* sp.? *Dosinia circinaria*, Deshayes; *Circe scripta*, Linné; *Pecten fumatus*, Reeve; *Pecten tegula*, Wood; *Spisula*

parva, Petit; *Ostrea Angasi*, Sowerby; *Ostrea cucullata; Nucula Strangei*, A. Adams; *Cryptodon globosum*, Forskal; *Cardium tenuicostatum*, Lam.; *Mytilus hirsutus*, Lam.; *Potamides ebeninus*, Bruguiere; *Lampania australis*, Quoy; *Natica Strangei*, Reeve; *Natica plumbea*, Lam.; *Natica conica*, Lam.; *Bulla australis*, Quoy & Gaimard; *Bittium granarium*, Kiener; *Nassa jonasi*, Dunker; *Calliostoma decorata*, Philippi; *Trochocochlea zebra*, Wood; *Liotia clathrata*, Reeve; *Risella lutea*, Q. & Gaim.; *Urosalpinx Hanleyi*, Angas; *Triton olearium*, Linn.

The mollusca do not call for any special mention, they are a mixture of both muddy-inlet and sandy-beach loving forms, such as one would expect to find in a deposit that must have undergone alterations of deposition. The Echinoderm is a deep water species, and in all probability was simply washed in.

Much interest attaches to the borings of the Oyster-boring Worm *Polydora*. In 1890, Mr. T. Whitelegge, of the Australian Museum, was deputed to investigate a disease that appeared amongst the oysters of New South Wales, on behalf of the Fishery Commissioners. It appears from his researches[1] that a marine worm, determined as above by Prof. W. A. Haswell, bores into and infests the shells of the oysters. The death of the oyster is then brought about by the decomposition of the mud after the death of the worms. At the time these investigations were made it was supposed by the oyster farmers and others to be a new disease, at any rate, so far as New South Wales was concerned, but we now find evidence of its existence at the remote period to which the deposition of bed (*e*) is to be referred. A few stumps of trees were also noticed enclosed in this bed. (Stumps Nos. 4 and 6 on longitudinal section *Plate* 9).

No. 4 Stump was a very large one, much eaten by boring on the outside, the borings, however, extending but a very short distance into the wood. This appeared to be *in situ*, the level of the top of the roots being three feet four inches below low water

[1] Aust. Mus. Records, 1890, I., No. 2, p. 41.

mark, the roots descending three feet. It was situated as near as possible in the middle of the canal, 2,100 feet north of Rickety Street Bridge. The roots rested on six inches of loamy sand passing down into a grey unctuous clay. This stump belongs to the Mahogany, *Eucalyptus* sp.

No. 6 Stump was also apparently *in situ*, its top being six feet eight inches, and the roots about two feet lower, below low water level. Remains of a Dugong, which will be described presently, were found in this bed, and unearthed in the presence of two of us. Four tomahawks have also been obtained from this bed, as we are informed, and our information leads us to the opinion that it is almost certain that they were obtained *in situ*. These also will be described presently.

(*f*) At the base of the estuarine blue clays is the horizon of the third peat bed, from a few inches up to five feet in thickness. Its upper surface is from ten feet to seven feet below low water. At the north-east end of the canal excavation, shown on the plan, and next to the upper dam, a very large number of tree stumps, as we are informed by Mr. W. Trickett, the overseer of the work, were unearthed, the majority being ten feet below low water. Of these, all but about three had been removed at the time of our visit (Nos. 1, 2, and 5). This submerged forest is also reserved for detailed description.

(*g*) Below the third peat horizon is white running sand, with thin bands of brown peaty sand, extending to a depth of at least three feet. Canal excavations have not gone below this depth, but bores put down for the foundations of the Rickety Street Bridge showed that the strata underlying (*g*) are as follows :—

8 ft. 6 in. Sand and mud.

12 ft. 0 in. Blue clay resting on Hawkesbury Sandstone.

(4) *Remains of the Dugong.*—One of the most important discoveries in connection with the Shea's Creek excavation is the discovery, by some of the workmen employed, of the bones of a Dugong. These were unearthed partly in the presence of one of us, near the junction of the two main tramlines running from

Rickety Street Bridge, at about seven hundred and sixty feet from the latter and fifteen yards from the western bank of the canal as now constructed. They were entombed in sandy clay, near the top of the estuarine clay marked (*e*), and just above the shell bed. They were five feet six inches to eight feet six inches below the present high water level, and a total depth of four feet six inches to seven feet six inches below the swamp surface level, previous to excavation. The bones were thus distributed through a thickness of about three feet of the sandy estuarine clay. The bones are those of *Halicore dugong*, Gmelin, sp., and were found confusedly heaped together. Although representing only a portion of the skeleton, we see no reason to doubt that they all belonged to one and the same individual. The following table shows the number found as compared with that of those of the living Dugong. The skull was recovered on two different occasions, the skull on one, the mandible on the other. The shoulder girdles, paddles, and pelvic bones are wholly wanting.

Name of Bones.	Dugong according to Flower.[1]	Shea's Creek Bones.
Cervical Vertebræ	7	1
Thoracic	19	17
Lumbar	4	3
Caudal	27	5
Ribs	38	26

[1] Flower, Osteol. Mammalia, 3rd ed., 1885.

The whole of the bones are in an excellent state of preservation, and are more or less fossilised, particularly the ribs, which nevertheless still retain a portion of the original animal matter. The structure of the bone substance of the ribs is very dense, and is with difficulty scratched with a knife on a fractured surface. The ribs in a recent Dugong are very heavy proportionately, dense and hard. A comparison of thin sections respectively of the ribs of this Dugong and of those of a recent Dugong shows that their mineralogical condition and structure are in both cases almost identical. We see no reason to doubt the identity of this Sirenian with the existing Dugong, and although unquestionably repre-

senting a large animal, it is not of greater size than the Dugong is known to attain.

The present southern limit of the Dugong is probably Wide Bay. although it was formerly to be caught in Moreton Bay. Its occurrence on the coast of New South Wales is very rare, indeed the late Mr. Gerard Krefft said, "the Dugong is not found on the coast of New South Wales,"[1] but Dr. E. P. Ramsay states that it has been "occasionally observed as far south as the Tweed and Richmond Rivers."[2] About two years ago Mr. Harry Stockdale, exhibited, at the Hotel Australia, a Dugong, which Mrs. Chinnery of Hunter Street, of whom the Dugong was purchased, informs us was caught in Broken Bay.

The late Mr. A. W. Scott, speaking of the Dugong's habits, says[3]:—"It is only the shallow waters of unruffled inlets and creeks, the sheltered mouths of rivers, the bays and the straits between proximate islands, that afford the necessary quiet, and the abundant submersed marine aliment essential for a permanent residence." This "aliment" is described by Macgillivray, as a slender, branchless, cylindrical, articulated seaweed, of a very pale green colour.[4]

Macgillivray gives[5] the following description of the method employed by the Cape York natives to capture the Dugong:—"When one is observed feeding close inshore, chase is made after it in a canoe. One of the men standing up in the bow is provided with a peculiar instrument used solely for the capture of the animal in question. It consists of a slender peg of bone, four inches long, barbed all round, and loosely slipped into the heavy, rounded, and flattened head of a pole, fifteen or sixteen feet in length; a long rope an inch in thickness, made of the twisted stems

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[1] Australian Vertebrata—Fossil and Recent, 1870, p. 6.

[2] Cat. Exhibits N. S. Wales Court, Gt. Internat. Fisheries Exhib., London, 1883, p. 53.

[3] Mammalia, Recent and Extinct, 1873, p. 52.

[4] Voy. "Rattlesnake," 1852, II., p. 25.

[5] *Loc. cit.*, pp. 24–25.

of some creeping plant, is made fast to the peg at one end, while the other is secured to the canoe. When within distance, the bowman leaps out, strikes the Dugong, and returns to the canoe with the shaft in his hand. On being struck, the animal dives, carrying out the line, but generally rises to the surface and dies in a few minutes, not requiring a second wound, a circumstance surprising in the case of a cetaceous animal, six or eight feet in length, and of proportionate bulk. The carcass is towed on shore and rolled up the beach, when preparations are made for a grand feast. The flesh is cut through to the ribs in thin strips, each with its share of skin and blubber, then the tail is removed and sliced with a sharp shell as we would a round of beef."

On the other hand, Mr. J. K. E. Fairholme,[1] says, the Dugong was captured by the blacks in Moreton Bay "by placing large nets across through which they knew the animals would pass from the feeding grounds."

Except on one of two hypotheses the presence of these bones in the Shea's Creek deposit is difficult of explanation, viz., either that the Dugong had strayed some considerable distance from its accustomed feeding ground, or else a carcase had floated in from seawards and become stranded. It could hardly have frequented such an inlet as Shea's Creek must then have been for feeding purposes, if the resemblance of the deposit to those now accumulating in the Parramatta River, and elsewhere under like conditions be any criterion for "Dugongs are much more strictly marine than Manatees, and their food is therefore chiefly restricted to sea-water algæ."[2] If, however, it be admitted that this Dugong was stranded alive at Shea's Creek, or at any rate at that part of Cook's River Estuary now represented by that odoriferous locality, the natural inference is that conditions more akin to those of the north-east Queensland coast existed there at that period.

(5) *Traces of Man's Presence.*—(*a*) *Tomahawks.*—On the north side of the second dam, 2,700 feet from Rickety Street, two

[1] Proc. Zool. Soc., 1856, pt. xxiv., p. 353.

[2] Ogilby, Cat. Austr. Mam. (Austr. Mus.), 1892, p. 63.

tomahawks were found in the first sump hole at a point opposite the middle of the dam, and one to the south-west, at the present site of the pump. Recently a third was found in a heap of mullock on the bottom of the canal on south-east side of the same dam. The two tomahawks from the first sump were six feet below low water, and therefore eleven feet below mean high water mark. One of these has come into our possession, and differs in no way from the oblong ovate type used by the aborigines, and is now exhibited.

(*b*) What appears to be a far more interesting piece of evidence of man's presence around Botany Bay at this epoch of its history is afforded by the Dugong bones, particularly the ribs. Many of these are scarred transversely and obliquely with deep scratches and cuts, especially at their distal ends. These incisions are most certainly not of recent execution, nor can we conceive any fortuitous circumstances, such as contact with sharp rock surfaces, that would produce them. They present the appearance of cuts and scratches that would be made by the direct blows of a sharp-edged stone tomahawk. The cuts are in themselves curved, with the central portion deeper than the sides, such as one would expect to be caused in the manner suggested. (See *Plates* 10, 11.) The esteem in which the Dugong's flesh was held by the blacks of the north-east coast is well known, and has been already referred to, and we are informed by Mr. R. Grant of the Australian Museum, that he has seen Dugong bones on the Queensland coast, with similar markings, that he knew had been handled by the aborigines. There is, therefore, the probability that at the time this Sirenian was stranded, and before the final geological changes had taken place that brought about the present aspect of the Botany and contiguous swamps, man was an inhabitant of the locality. One other item of evidence there is—the burnt off stumps in the forest bed, although this is of a much less conclusive nature.

(6) *The Submerged Forest.*—As already mentioned, a very large number of stumps of trees were found, chiefly just to the south-west of the northern dam. The greater number of these were *in*

situ, just as they grew when their stems were attached. A few were lying over on their sides. At the time of our examination, only about three trees were still left *in situ* on this horizon, viz., Stumps 1, 2, and 5, as shown on the longitudinal section, (*Plate* 9).

No. 1 Stump lay at the bottom of the canal, and had a large "buttress," the roots spreading out in their natural position, some with rootlets attached at least six inches long by two inches in diameter. The root rested on and was implanted two feet in dark clayey sand, above the top of the stump was one foot of peaty material, and then the estuarine bed (*e*), there six feet thick. Mr. E. F. Pittman, the Government Geologist, traced one of its roots by digging for fully six feet from the centre of the stump—the root extended horizontally and slightly downwards—and satisfied himself as to the stump being really *in situ*. The root was still over four inches thick at the furthest point to which it was traced. This stump is ten feet below low water, and belongs to the Swamp Mahogany, *Eucalyptus botryoides*.

No. 2 Stump showed evidence of having been burnt off at the top, and the roots also appeared charred. It belongs to Honeysuckle, *Banksia (B. serrata)*. The subsequent discovery of the cones by Mr. R. Baker, proves the existence of this species in the submerged forest. It is also ten feet below low water, and is *in situ*.

No. 5 Stump, occurring at the same level, was also dug around by us to make sure that it was *in situ*, and the roots were found to radiate for at least four feet from the stump. This stump belonged to the Mahogany, *Eucalyptus (? E. resinifera)*. Mention should also be made of the fact that during the early part of the work, Mr. A. S. Patison, surveyor in charge at Shea's Creek, followed one root belonging to a stump in the bottom of the canal near the upper dam, for twenty-one feet. The stump to which it belonged had a diameter of two feet six inches. No doubt, therefore, exists in our minds as to the stumps described above being really *in situ*, and Mr. E. F. Pittman, the Government Geologist concurs with us in this opinion.

III.—Deductions.

(1) *As to Submergence.*—It is not our purpose to enter here into a discussion of the general question as to whether evidence, such as that afforded by the submerged forest, points to a downward movement of the land or to a rise in the level of the ocean. A very brief summary, however, of general views held on the subject of beach lines will perhaps be not out of place. Of late years eminent geologists, notably Suess, have argued that, in the case of raised beaches and submerged land surfaces, the evidence points rather to an alteration in the level of the ocean than to a definite upward or downward movement on the part of the earth's crust. Among causes which affect the general level of the ocean or distort its surface may be mentioned the following:—

i. Development of ice masses at the Poles.
ii. Bending of the earth's crust.
iii. Lateral attraction of continental masses.
iv. Sedimentation.
v. Position of the shore with regard to the tide wave.
vi. Inflow of freshwater.
vii. Difference in density of the ocean water at different localities due to varying conditions of evaporation, rainfall, and currents.
viii. Direction of prevalent winds.
ix. Hydration of the lithosphere.

With reference to (i.) Lord Kelvin[1] has shown that the alteration in sea level, during an ice age, in a non-glaciated hemisphere, (on the assumption that the glaciation of the Northern and Southern Hemispheres was alternate) would amount to, (certain other premises being granted) as much as three hundred and twenty to three hundred and eighty feet. Mr. Warren Upham[2] has calculated that during the maximum glaciation of the Ice Age in the Northern Hemisphere, the sea surface over the whole globe may

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[1] Popular Lectures and Addresses, p. 330.

[2] The Ice Age in North America—G.F. Wright, 1889, p. 579.

have been reduced by as much as one hundred and fifty feet, while Mr. R. S. Woodward[1] has estimated that gravitation towards the ice in the Northern Hemisphere would further depress the ocean in the tropics and in the Southern Hemisphere to the amount of from twenty-five to seventy-five feet, while it would raise the level near the borders of the ice-sheets to counter-balance approximately the depression due to the diminution of the ocean's volume, and would lift portions of the North Atlantic and of the Arctic Sea, perhaps two or three hundred feet higher than now.

With regard to (ii.), Suess states that, if Krümmel's formulæ be taken for the cubic capacity and depths of the oceans, and that if it be assumed that the shores of the ocean were everywhere vertical and that the Greek Levantine Sea and the Black Sea did not exist, and then the depressions were to be formed in which the Black Sea and Greek Levant now lie, there would be a eustatic negative movement of the ocean to the amount of four mètres. In order, therefore to produce a change in level of the sea surface equal to that of which we have evidence at Shea's Creek, it would be necessary for a rise to have taken place in the ocean floor sufficient to displace more water than now lies in the Black Sea and Greek Levant.

With regard to (iv.) Sedimentation, it would be necessary to denude a thickness of ten mètres off the whole area of the land, and deposit it in the sea in order to produce an elevation in the sea surface of four mètres. At the rate of one foot in 50,000 years, this would occupy a period of 1,637,000 years, a period of time vastly in excess of that needed for the production of all the phenomena observed at Shea's Creek.

Suess[2] states that a strong argument against "Raised Beaches" being attributable to movements of the solid crust of the earth rather than to changes in sea-level, is that that they appear to be wholly independent of such folding movements as the earth's crust

[1] United States Geological Survey, Sixth Annual Report pp. 291 – 300, and Bulletin No. 48, "On the Form and Position of the Sea-Level."

[2] Das Antlitz der Erde, Suess, Vol. II., p. 509.

can be proved to have undergone in the past, and is probably still undergoing in the present.

Whether the change of level at Shea's Creek be due to the movement of the land or that of the water is uncertain, but there is evidence, at all events, of an alteration in the level of the land and sea in recent geological time to the amount of about fifteen feet, as the trees found *in situ* by us at a depth of fifteen feet below high water all belong to genera which do not flourish below the level of high tide. This is probably one of the most important pieces of evidence yet obtained in any part of Australia to prove submergence in recent geological time.

With regard to the question as to whether the submergence is still in progress, the fact might here be mentioned that Mr. G. H. Knibbs, L.S., and one of the writers, with the view of possibly obtaining some evidence as to whether the coastal strip between the eastern escarpment of the Blue Mountains and Port Jackson is still subsiding, have levelled carefully across the hinge of the fold which forms the inland boundary of the depressed area. Marks have been cut in the rock, and Mr. Knibbs proposes to to relevel between the marks three or four times a year. Possibly some results may be obtained in the course of a few years, and might tend to throw light on the question, as to whether the crust is subsiding or the ocean rising in the neighbourhood of Botany Bay.

(2) *Evidence as to the Geological Antiquity of Man.*—A second deduction, perhaps more interesting than the first, may be drawn from the Shea's Creek section, with reference to the geological history of man in Australia. As already stated, the bones and skull of the Dugong exhibited, show conclusive evidence of having been hacked by human agency, the cuts being exactly of the kind as would be produced by blows from a blunt edged implement such as a stone tomahawk. We may look upon it as an established fact therefore, that this Dugong was cut up and no doubt eaten by the Aborigines. We have been unable to obtain any evidence to show that the Aborigines in the neighbourhood of Sydney ever

fed upon the Dugong, and we should be glad of any information bearing on this subject. The date of this ancient Dugong feast at Shea's Creek cannot be stated in terms of years. As regards the downward limit in time we have the evidence of the shells and of the trees, all of which belong to existing species. The date of the feast cannot therefore be moved back below the limits of Post-Tertiary time. In view of the probable specific identity of the species of the Dugong now discovered with existing species, it is questionable whether it is likely that the date can be carried back into Pleistocene time.

As regards the upward limit, the following considerations suggest themselves :—The uppermost of the bones discovered lie at a level of six inches below low water, and the lowest at three feet six inches below low water. It might be argued from this that the animal was stranded in shallow water at low tide and cut up in the shallow water by the Aborigines at a time when the general level of the ocean was much as it is at the present day. The occurrence, however, of the peaty horizon (*d*) just six inches above where the remains of the Dugong were found seems to preclude this hypothesis, as the evidence shows that after the skeleton had become silted up in the estuarine beds, swamp conditions extended over the spot, as shown by roots of shrubs, found in this peaty horizon. It would obviously have been impossible for such shrubs to grow below sea level, and they would have been at least five feet below mean high tide, unless the level of the ocean has risen since the burial of the Dugong, as must obviously have been the case.

The evidence seems to point rather to the following conclusions:—The Dugong having been captured and killed by the aborigines, its body was towed or dragged in the water during flood tide until the water became too shallow to tow it any further inland. It may then have been taken into water about three feet deep or less, and as the lowest of the bones are a trifle over three feet below present lower water, the level of present low water probably represented the level of high water at that period ; in other words

the general level of the ocean may have risen five feet with regard to the level of the land since the death of the Dugong. The carcase was probably for the most part carried off by the Aborigines piece-meal, and as there would have been enough flesh on the bones to admit of their cutting and coming again, the feasting would probably have been prolonged for more than one day. Hence it is all the more probable that the carcase of the Dugong would have been taken to near high water mark, where it would have been comparatively safe from any but human carnivores, than have been left to the tender mercies and maws of the sharks, as it would have been had it been allowed to remain at low tide level. The skeleton, after being stripped of its flesh, was covered over with mud by the wash of the tide, and sediment brought down by, perhaps, the ancestor of the modern Shea's Creek, and the spot having been temporarily reclaimed by the silting, it was possible for swampy vegetation to overspread the spot, and this actually happened. Then followed a slight subsidence of the land or rise of the ocean during which the mud and shells were brought in which form bed (*c*) above the peaty horizon (*d*). This movement continued until the peaty horizon (*d*) was gradually carried five feet below the level of mean high water. During this time the sand forming bed (*b*) was accumulating, the peaty horizons in it perhaps marking pauses in the relative movement of ocean and land surfaces. If these inferences are correct, we are led to the somewhat startling conclusion that Neolithic man may have inhabited Botany Bay when the ocean level was about five feet lower than at present.

If the four stone tomahawks found at Shea's Creek were *in situ* as there seems every reason to suppose, and if they had not worked down in the silt, (and it is all but impossible that they could have worked down through the peaty layer (*d*) into the position in which they are said to have been found), they would show that man, sufficiently civilised to manufacture such implements, inhabited this region at perhaps even a more remote period, one of the tomahawks having been found close to the horizon of the

third peat bed (*f*) about seven feet below the level of low water. The burnt stump in the submerged forest is possible, though not certain evidence, of the presence of man.

Previous to this discovery evidence as to the geological antiquity of man in eastern Australia was of a very meagre character. It has already been summarised by one of the authors, Mr. R. Etheridge, Junr.[1] Briefly stated the evidence is as follows:—

A. *Direct.*—(1) In New South Wales a human molar tooth, more or less fossilised, was found by Mr. Gerard Krefft, a former Curator of the Australian Museum, at the Wellington Caves in the cave earth, associated with the remains of extinct animals, *Diprotodon* and *Thylacoleo*.[2] There is, however, some doubt as to whether this tooth really occurred *in situ* in the cave breccia containing the bones, or whether it may not have been introduced subsequently through a crack into the breccia. The Scotch verdict of "not proven" is considered to apply to this case.

(2) In the Hunter River district, sandstone beds covered by about thirty feet of alluvial material are said by Bennett to show axe-marks produced by the Aborigines, when grinding their stone tomahawks.[3] These axe-marks, however, need not necessarily have been very old, as the Hunter and Paterson Rivers frequently change their courses rapidly during floods, and so a bed of sandstone, which may, previous to a flood, have been exposed in the bank of the river at the summer level, may become covered with twenty feet or more of alluvium, if during the flood the river should suddenly change its course.

(3) On the Bodalla Estate a stone tomahawk was dug up at a depth of fourteen feet, under alluvial deposits, as referred to by Mr. C. S. Wilkinson.[4]

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[1] Proc. Linn. Soc., N. S. Wales. Vol. v., 1890.—Has man a Geological Antiquity in Australia, pp. 259–266.

[2] *Op. cit.*, p. 263, and Geol. Mag. 1874, I., p. 46.

[3] *Op. cit.*, p. 261, and Bennett, History of Australian Discovery and Civilization, p. 263, (8° Sydney, 1867).

[4] Notes on the Geology of New South Wales—Department of Mines, Sydney, 1887, p. 90. (4° Sydney, 1887, By Authority).

(4) At most sheltered spots along the coast of New South Wales where shell life is abundant, as along the shores of coastal lagoons and estuaries, there are to be seen mounds of shells, accumulated by the Aborigines, and consisting of the shells of edible molluscs, fragments of charcoal, bones of fish etc., together with skinning knives made of flakes of hard rocks, bone needles, stones for opening and cracking shells, etc. From the position of some of these shell mounds, on the edges of swampy flats formed of silt brought down by rivers into what were probably open estuaries at the time that the Aborigines gathered shells there, it is evident that the shell mounds must be of somewhat ancient date.

(5) Sand dunes—Remains of some antiquity, of human workmanship, have been discovered in some of the sand dunes of Victoria, as described by the late C. S. Wilkinson,[1] and one of the writers.[2] These remains consist of flint chips, a sharpened stone tomahawk, and several bone spikes or needles. In view, however, of the rapid rate at which dunes form and drift these may not necessarily have had a very high antiquity, though as they were lying beneath sand dunes at least two hundred feet high, they must have been tolerably ancient.

B. *Indirect Evidence.*—This evidence would argue a much greater antiquity for man in Australia than the above quoted direct evidence. It is chiefly twofold. (1) The existence of man in Tasmania argues that he crossed from the Australian continent thither probably either before the formation of Bass Strait, or, at all events, if he crossed in canoes, at a time when Bass Strait was far narrower than at present, as neither the Victorian nor Tasmanian Aborigines had any knowledge of the art of building sea-going canoes, as far as we are aware. If the first arrival of man in Tasmania took place at the most recent time when Tasmania was united to Victoria, it must date back certainly many thousand years. There is, however, good ground for supposing

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1 Report on the Geology of the Cape Otway District, 1865, p. 2.

2 R. Etheridge, Junr., Trans. and Proc. R. Soc. Victoria, 1876, Vol. XII., pp. 3, 4; and Records Geol. Survey N. S. Wales, 1889, I., pt. i., p. 15.

that Tasmania was already disunited from the mainland before the advent of man into that island, because the dingo did not find its way into Tasmania, and the dingo was probably introduced into Australia by man. At the present there are not only no dingoes in Tasmania, but not even the slightest vestige has been found of the remains of fossil dingo in Tasmania. The conclusion therefore, may be provisionally drawn, that Bass Strait was already in existence at the time of the advent of early man and his canine companion, the dingo, in Australia. He perhaps crossed into Tasmania by means of small canoes, but not judging the dingo to be an agreeable cabin companion left him behind.

(2) The Tasmanian Aborigines never advanced beyond a Palæolithic stage in the manufacture of their stone weapons, always producing a cutting edge by rough chipping, never by grinding. By far the larger number of the known stone implements of the Australian Aborigines are on the other hand of a Neolithic type, and mostly very neatly fashioned by grinding. This great difference in the manufacture of their stone implements implies that the Tasmanian Aborigines must have been long isolated from the Australian Aborigines.

(3) The next piece of indirect evidence is based on the assumption, (a very probable one,) that the dingo was introduced into Australia by man. If this be the case, it follows that to whatever period the date of the dingo can be pushed back, the date of man in Australia can be equally extended back into the past. Remains of dingo have been discovered in association with those of various extinct animals in a cave at Gisborne, Mount Macedon, and also from Pliocene deposits near Colac, Victoria, as well as from the Wellington Cave bone breccias with *Diprotodon* in New South Wales. The complete skeleton of a dingo has also been discovered under a depth of sixty-two feet of basalt tuff from an extinct volcano at Tower Hill, near Warnambool in Victoria. There is not even a legend among the Aborigines of man having seen alive any of the extinct animals, such as the *Diprotodon*, with which the remains of the dingo have been found to be associated at the above

mentioned localities. At a time when the dingo was contemporaneous with such huge herbivores as the *Diprotodon* and the *Nototherium*, the climate of Australia must have been far more humid than at present, so that the Central Plains supported a dense growth of vegetation surrounding swamps which are known in the neighbourhood of Lake Eyre to have been infested with crocodiles. A great lapse of time is needed to account for this great change in the physical geography of Australia. We may conclude, therefore, that man, if contemporaneous with the earliest arrived dingoes, has probably a considerable geological antiquity in Australia, that he may have witnessed the volcanic eruptions in Victoria and South Australia, and that he may have crossed Bass Strait in his canoes at a time when that strait, now about one hundred miles wide, was in the condition of one or more narrow channels. It is, however, of course at present by no means certain that the dingo was introduced into Australia by man, and any conclusions based on such an assumption must therefore be looked upon as only provisional and tentative.

That aboriginal man may have witnessed some of the latest volcanic eruptions in Victoria is rendered probable by the remarks of Mr. James Dawson, who makes the following statement[1]:—"An intelligent Aboriginal distinctly remembers his grandfather speaking of fire coming out of Bo'ok"—a hill near the town of Mortlake in Western Victoria—"when he was a young man. When some of the volcanic bombs found among the scoriæ at the foot of Mount Leura were shown to an intelligent Colac native, he said they were like stones which their forefathers told them had been thrown out of the hill by the action of fire."

With the exception of the meagre direct evidence just described, the evidence obtained at Shea's Creek, as far as we are aware, is the best direct evidence hitherto obtained to show that the existence of man in eastern Australia can probably claim something approaching to a geological antiquity, as is implied by the fact

[1] Australian Aborigines, 1881, p. 102.

that the Pacific Ocean and the Australian land have changed their respective levels by as much as fifteen feet, since the existence of Neolithic man at Botany Bay.

We desire to gratefully acknowledge the courtesy of Mr. Cecil W. Darley, M. Inst. C.E., in placing his offices at our disposal and allowing his officers to assist us; and we are also indebted to him and to Mr. McLachlan, Under Secretary for Mines and Agriculture, for the loan of the stone tomahawks dug up at Shea's Creek. We also acknowledge the services rendered us during our exploration of Shea's Creek by Mr. A. S. Patison, the surveyor locally in charge of the work, and by Mr. W. Trickett, the overseer, and for much important information communicated to us by them. We are under a special obligation to Mr. J. Jennings of the Australian Museum for the naming of the shells, and to Mr. R. Baker of the Technical College for determining the various kinds of timber taken from the different stumps of the submerged forest. We also beg to thank Mr. W. F. Smeeth for his preparation of the microscopical sections of the Dugong bones, which has proved no light task, and to Mr. Whitelegge of the Australian Museum for the photographs exhibited showing the excavation at Shea's Creek. We also have to thank Mr. Halligan for kindly supplying sections of the Rickety Street Bridge bores, and Mr. H. E. C. Robinson for preparing the enlarged diagrams to illustrate this paper.

CORRIGENDA.

Page 159, line 8, delete 'and Commodore Charles Wilkes, U.S.N.'
" line 9, for 'were,' read '*was*.'
" line 10, for 'They state,' read '*He states*.'

NOTE ON RECENT DETERMINATIONS OF THE VISCOSITY OF WATER BY THE EFFLUX METHOD.

By G. H. KNIBBS, F.R.A.S., L.S.,
Lecturer in Surveying, University of Sydney.

[*Read before the Royal Society of N. S. Wales, September 2, 1896.*]

1. In a paper on the above subject,[1] read before this Society 3rd July last year, reference was made (Note 4, p. 132) to the viscosity measurements of Thorpe and Rodger. These, since to hand,[2] give two series of values for the viscosity of water, one between the limits 0° and 100° C., the other between the limits 0° and 8° C., the latter being obtained in order to ascertain whether the viscosity curve shewed any peculiarity at the temperature of maximum density. I propose, therefore, to briefly consider how far their determinations, and those of other investigators whose work was previously overlooked, modify the results given in my paper; and thus, by completing the review of the subject, to indicate the present state of knowledge in regard to the evaluation of the viscosity constant for water.

2. *Theory of Correction of Pressure.*—Contemporaneously with the publication of Couette's deduction, that the pressure head in the reservoir supplying the efflux tube, should be reduced by the amount U^2/g, Gartenmeister[3] stated that Finkener had, in an unpublished treatise, shewn that that correction was the proper one. In 1891 Wilberforce[4] pointed out the principal defect in Hagenbach's reasoning, which led the latter to adopt the coëfficient $2^{-\frac{1}{3}}$, for the value of m in the equation

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[1] Journ. Roy. Soc. N. S. Wales, Vol. XXIX., pp. 77 – 146, 1895.

[2] On the relations between the viscosity of liquids and their chemical nature.—Phil. Trans. Vol. 185, Pt. 2, pp. 397 – 710, 1895.

[3] Zeitschrift für physikalische Chemie, Bd. 6, p. 524, 1890.

[4] On the calculation of the coëfficient of viscosity of a liquid from its rate of flow through a capillary tube.—Phil. Mag. Ser. 5, Vol. 31, pp. 407 – 414.

$$P_0 = P - m\,\frac{\pi^2 R^4}{\rho\, q^2}$$

equation (3) page 95, in my previous paper. Wilberforce himself agrees with Gartenmeister, for he also assigns the value unity to the factor m, regarding it as defective only by reason of the viscous resistance of the fluid as it approaches the tube.

Thorpe and Rodger call the correction referred to, the Couette-Finkener correction for the kinetic energy of the flow.[1] I have already drawn attention to the fact, that it should be associated with Neumann's name, since he deduced it as far back at least as 1860, in the September of which year it was quoted by Jacobson as Neumann's, see page 97 of my former paper; that experimentally its value appears to vary considerably; that by kinetic theory Boussinesq had shewn it should be about 1·12; and that this last value should be used in the absence of experimental knowledge for particular cases.

The examination of the circumstances of flow, near and just within the terminals of a tube, will probably contribute important results; according to a recent number of the Journal de Physique, the latter element is at present being studied by Aignan.[2] But however well ascertained these circumstances are, an accurate evaluation will necessitate a disposition of apparatus such as will reduce their influence to a minimum; this is abundantly evident from the discussion in Section 8 of my former paper.[3]

3. *Theory of correction of length of tube.*—In Thorpe and Rodger's paper previously referred to, Couette's proposed correction to be applied to the length of the tube to equate the resistances at the terminals, and to take account of the various circumstances of the motion thereat, has been discussed. In the reduction of their observations no notice has been taken of the correction, because their values for the viscosity were found to agree

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[1] Phil. Trans., Vol. 185, pp. 435 – 438.

[2] Ecoulement de l'eau dans un tuyau cylindrique.—Journ. de Phys. 3me sér. t. 5, pp. 27, 28, 1896.

[3] pp. 93 – 103.

well with Poiseuille's without applying it. This seems hardly a satisfactory reason for rejecting an admittedly rational correction: the only justification is the one indicated in Section 9 of my former paper, see pp. 103 – 107, viz., that experimentally the length-correction appeared to vary and to be either positive or negative in sign. The instance selected by Couette from Poiseuille's results and compared with his own, merely chanced to agree, and a complete discussion of Poiseuille's observations shewed that the fortuitous agreement was evidentially worthless. Aignan's investigation will perhaps throw some light on this point, but it seems that there is no alternative but to follow some such method as that previously indicated, or else Couette's method of simultaneous flow through two tubes, using however the more rigorous reduction which takes account of the absolute amount of the pressures and the ratio of the radii of the tubes, and for which I supplied a formula, (43), in my former paper.

4. *Measurements of Viscosity* not previously discussed.

Slotte 1883.—Slotte's 1883 observations[1] of times of efflux give values for approximately every ten degrees of temperature from 0° to 90° C., and give also a value for 97° C. The relative fluidities hereinafter quoted, have been found by correcting his efflux times by formula (5) of my former paper (p. 98), m being taken as 1·12. In the small interpolation involved in consequence of his observations not being made exactly at whole five degrees, second differences have been taken into account, as also in the extrapolation from 97° to 100° C. Slotte himself had used Hagenbach's correction, *i.e.*, m was taken as 0·79 instead of 1·12. The dimensions of his tubes are not known with sufficient accuracy for absolute values of the viscosity, but as his observations are discussed only for the evaluation of relative fluidities at different temperatures, the defect does not prejudice the results. His corrected times of efflux, T_o in formula (5) above referred to, range between 1447·2

[1] Ueber die innere Reibung einiger Lösungen und die Reibungsconstante des Wassers bei verschiedenen Temperaturen.—Wied. Ann. Bd. 20, pp. 257 – 267, 1883.

seconds and 241·9 seconds, and these are the means of from two to four observations.

Pagliani and Batelli 1885.—Pagliani and Batelli's observations[1] were made at the temperatures 0°·2, 0°·5, 10°·9 and 11°·25 C, the effiux times ranging between 622·7 and 437·5 seconds. Their reduction give 1372 as the value of the fluidity at 10° C., that at 0° being 1000, which happens to be identical with Slotte's determination, see table of results hereinafter.

Traube 1886.—Traube's efflux measurements[2] were made with two tubes, from two to four observations being taken at each 10° from 0° to 60° C., but his temperatures are apparently uncertain to 0°·1 below 30° and 0°·5 at the higher temperatures, these uncertainties producing however but insignificant errors in regard to his purpose.[3] His efflux times range between about 96 and 366 seconds. As he used Hagenbach's correction his results have been reduced afresh, and Boussinesq's correction applied, *i.e.*, $m = 1{\cdot}12$. The tabulated results are the means of his two measurements which differed in no case more than 0·7%.

Noack 1886.—In the same year Noack[4] also made efflux observations between the same limits, but at about 5° instead of every 10°. The fluidity values hereinafter given were obtained by increasing his kinetic energy correction by 41% as he had used Hagenbach's factor. A complete and independent reduction could not be undertaken because the necessary data were lacking. In the reduction to every fifth degree, second differences were taken into account, and as the interpolations were never for more than 1·6° this procedure was amply rigorous.

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[1] Sull' attrito interno nei liquidi.—Atti d. R. Accad. Torino, Vol. 20, pp. 607 – 634, 1885.

[2] Ueber die innere Reibungsconstante und die specifische Zähigkeit organischer Flüssigkeiten und ihrer wässerigen Lösungen.—Ber. Chem. Gesell. Bd. 19, pp. 871 – 892, 1886.

[3] See p. 875.

[4] Ueber die Fluidität der absoluten und verdünnten Essigsäure.—Wied. Ann. Bd. 28, pp. 666 – 684, 1886.

The recorded efflux times, observed to 0·1 second, ranged from about 216 to about 681 seconds, and the determinations for each tabulated temperature were from two to eight in number.

Thorpe and Rodger 1894.—Thorpe and Rodger's measurements of the viscosity of water, made in connection with their important contribution to chemical physics hereinbefore referred to, give the results of no less than 13 double observations of the viscosity of between 0° and 8·01° C., and also those of double observations at about every 8°·5 from about 4°·5 to about 99°·7 C. Their published data are incomplete, and it is not therefore possible to undertake a thoroughly independent reduction ; but as they have given the applied corrections, in which they assumed m to be unity instead of 1·12, I have further reduced their viscosity values by subtracting 0·12 times the correction, and from these corrected values have obtained the relative fluidities, ascertaining them for every 0°·5 between 0° and 8° by a system of parabolic interpolations, and similarly for every 5° from 0° to 100°.

They mention a formula deduced for them by Rücker, which is identical with formula (18) page 112 of my former paper. The method employed to determine the axes of the elliptical section of the tube is well worth noting. The *ratio* of the axes was observed optically, and the semi-axes were found from the volume and the ratio, on the assumption that the latter was constant throughout. This method, however is, as I have previously shewn, satisfactory only when both the ratio and the area of the section are actually constant for the whole length of the tube. For absolute values of the viscosity the data are therefore not satisfactory, in fact Poiseuille's tubes are the only ones that appear, so far, to have been thoroughly measured.

The imperfect knowledge of the effective radius of the tube, however, in no way prejudices the relative values of the fluidity for various temperatures ; it can only affect the *absolute* value of the viscosity constant. The time of efflux ranges from about 160 to about 1000 seconds. The former time is rather short for a thoroughly satisfactory determination. The general disposition

of the apparatus,[1] seemed to leave little to be desired, and the results are remarkably consistent. But so also are Slotte's which give very different values for the fluidity at the higher temperature.

At the suggestion of Bodington, Thorpe and Rodger have called the efflux apparatus for viscosity measurements the *glischrometer*.[2]

5. *Relative Fluidity about the temperature of maximum density.* —In my former paper, Section 25, p. 139, I shewed that between the limits 0° to 10° C., the fluidities deduced from combining Poiseuille's, Graham's, and Sprung's observations indicated a curve of the form

$$1 + a\tau - \beta\tau^2$$

and as the sign of the coefficient β was + in a more extended temperature limit, there was an inflexion in the general curve. Thorpe and Rodger's work does not shew this peculiarity, and I think disposes of the supposition. The following table in which the first column gives the observed, and the second the computed, values from the formula

$$f' = 1 + 0{\cdot}0225\tau + 0{\cdot}0005\tau^2 \ldots\ldots\ldots(1)$$

will make this obvious.

Relative Fluidities of Distilled Water 0° to 8° C., computed from Thorpe and Rodger's viscosity measurements—

Temp.	Observed.	Computed.	Temp.	Observed.	Computed.
0°	1000	1000	4°·5	1157	1156
0·5	1014[1]	1016	5·	1176[2]	1175
1·	1033	1033	5·5	1190	1194
1·5	1050	1050	6·	1214	1213
1·	1067	1067	6·5	1232	1232
2·5	1085	1084	7·	1251	1252
3·	1101	1102	7·5	1270	1272
3·5	1119	1120	8·	1289[3]	1292
4·	1138	1138	13·53	1503	1531

NOTE—Poiseuilles values :—[1] 1015 : [2] 1177 : [3] 1287.

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[1] Phil. Trans. Vol. 185, p. 413.

[2] Evidently from $\gamma\lambda\acute{\iota}\sigma\chi\rho$os, gluey or viscous.

It will be noticed that equation (1) expresses the observed values with great precision as far as 7° or 7·5°, and that at 13·53° there is a sensible divergence. Since the curve for Poiseuilles results as far as 45° was well represented by

$$f' = 1 + 0{\cdot}03395\tau + 0{\cdot}000235\tau^2$$

the coefficient β being less than half of what it is in the preceding equation, it is evident that the radius of curvature of the fluidity curve diminishes as the temperature increases. This law is borne out by the extension from 45° to 100° C., that is, the curve throughout becomes flatter as the temperature increases. Both Slotte's and Thorpe and Rodger's results shew that the second differences are very much smaller for the higher temperatures, say 50° to 100°; Slotte's second differences are however only about $\frac{1}{9}$ of Thorpe and Rodger's.[1] There is no satisfactory indication of any peculiarity, other than this relative rapid change of curvature, at the temperature of maximum density.

6. *Relative Fluidities 0° to 100° C.*, deduced from the efflux measurements of various investigators. The following table gives the results, deduced as explained, from the data furnished by the investigators whose initials are noted as follows :—P = Poiseuille, G = Graham, mean of tubes *D* and *E*, R = Rosencranz, S = Slotte, T = Traube, N = Noack, and TR = Thorpe and Rodger. The year in which their observations were made is also quoted. The computed results given in the last column are obtained by formula (2) hereinafter given, the value at zero being taken as 100.

Relative Fluidities 0° at 100° C.

Temp.	P. 1846	G. 1861	R. 1877	S. 1883	T. 1886	N. 1886	TR. 1894	Computed.
0°C.	1000	1000	1000	1000	1000	1000	1000	100
5	1177	1183	...	1181*	1178*	1178	1176	118
10	1363	1369	...	1372	1365	1375	1365	137

* Values obtained by parabolic interpolation.

[1] Can it be possible that Thorpe and Rodger's repeated use of the one sample of water—flowing to and fro from bulb A to bulb B has anything to do with their high values of the fluidity at the higher temperatures?

Relative Fluidities 0° to 100° C.—continued.

Temp.	P. 1846	G. 1861	R. 1877	S. 1883	T. 1886	N. 1886	TR. 1894	Computed.
15	1557	1580	...	1574*	1557*	1575	1562	157
20	1771	1796	...	1785	1758	1796	1772	178
25	1992	2021	...	2005*	1977*	2020	1992	200
30	2226	2240	...	2233	2206	2233	2225	223
35	2479	2493	...	2473*	2445*	2484	2466	247
40	2738	2758	2730	2717	2685	2726	2716	272
45	3010	3018	3020	2961*	2917*	2974	2976	298
50	...	3308	3270	3214	3144	3214	3246	325
55	...	3549	3540	3477*	3368*	3479	3517	353
60	...	3834	3720	3744	3589	3763	3797	382
65	...	4165	3980	4017*	...	...	4086	412
70	...	4461	4210	4294	...	...	4385	443
75	...	...	4430	4571*	...	...	4693	...
80	...	...	4620	4849	...	...	5003	...
85	...	...	...	5128*	...	...	5316	...
90	...	...	5460	5409	...	...	5633	...
95	...	...	...	5695*	...	...	5955	...
100	...	...	...	5983	...	...	6282	...

* Values obtained by parabolic interpolation.

An examination of the table and of the experiments from which the values given are deduced shews :—

(*a*) That the relative fluidity has been ascertained to within 1% from 0° to 50° C.

(*b*) That from 50° to 100° C. the uncertainty increases to 5%.

(*c*) That this large uncertainty is apparently not explained by possible errors of observation either of temperatures, efflux times, or of the dimensions of the apparatus.

(*d*) That determinations of viscosity, to the order of precision 0·1%, will involve an investigation of the cause of the large discrepancies in previous results.

(*e*) That between the limits 0° and 70° C., the relative fluidity may be expressed to two places of decimals by the formula

$$f' = 1 + 0{\cdot}035\tau + 0{\cdot}0002\tau^2 \quad \ldots\ldots\ldots (2)$$

or between 0° and 7° C. to three places of decimals by formula (1) hereinbefore given.

M—Sept. 2, 1896.

On the CONSTITUENTS of the SAP of the "SILKY OAK," *GREVILLEA ROBUSTA*, R. Br., and the PRESENCE of BUTYRIC ACID THEREIN.

By Henry G. Smith, F.C.S.

[*Read before the Royal Society of N. S. Wales, October 7, 1896.*]

During last year, the author in conjunction with Mr. J. H. Maiden, carried out investigations on a deposit of Succinate of Aluminium, found existing in the timber of *Grevillea robusta*, R.Br. the results of which were communicated to this Society in a paper[1] read on the 6th November.

The occurrence of succinic acid in a deposit of this character appears to be extremely rare, and the origin of its formation was a matter for some consideration. As was pointed out at that time, it appeared probable, from the result of our inquiries, that the acid might have been formed by the alteration of malic acid, together with the formation of acetic acid, as a trace of the latter acid had been identified in the deposit. As it had not been possible at that time to obtain the sap from this tree, it was of course impossible to say whether malic acid was present or not, so the matter was allowed to remain open until the sap could be investigated. Special efforts were made to obtain, if possible, some of the sap, and it is to the kindness of Mr. W. P. Pope, Forester, in the Lismore District, of this colony, that I am indebted for the present material, he having collected and forwarded a small quantity of the sap for investigation.

Mr. Pope informs me that he obtained the sap by felling the tree, cutting it into lengths, which were then placed on their ends, so as to enable them to drain. He says that the sap would not run if the tree was merely cut into, or even if cut quite off, but

[1] On a natural deposit of Aluminium Succinate in the timber of *Grevillea robusta*, R. Br.

that it was necessary to cut the log into short pieces before the sap would run. The sap is thus obtained without much difficulty, but he thinks that the spring is the best time to procure it. The present sample was obtained during the month of February last. It will be noted that the method adopted by Mr. Pope to obtain this sap, is that by which the aborigines of the dry Western District of this Colony used to obtain a liquid from the roots of the "Mallee" trees to allay their thirst. The following extract will explain this :—"Looking as if they understood me, they therefore hastened to resume their work, and then I discovered that they dug up the roots for the sake of drinking the sap. It appeared that they first cut these into billets, and strip the bark and rind off, sometimes chewing it, then holding up the billet and applying one end to the mouth the juice drops out. We now understood for what purpose those short clubs, which we had seen the day before, had been cut."[1]

The Organic Acid.

When received, the sap had a specific gravity of 1·0036 at 15·5°C. It was strongly acid to test paper, and had rather an unpleasant smell, indicating by its odour the presence of butyric acid. The determination of the acid was at once proceeded with. The total acidity determined by standard soda, 1 cc. = ·0088 butyric acid, using phenol-phthalein as indicator, and after air had been drawn through the sap to remove CO_2 if present, was as follows :—10cc. of the original sap required 1·9 cc. of soda solution, or 100 cc. required 19 cc.; 50 cc. were then distilled almost to dryness, a small quantity of water added, and the remainder of the 50 cc. distilled over; 10 cc. of this distillate required 1·4 cc. of soda solution or 100 cc. required 14 cc., equal to ·1232 gram. of butyric acid, so that by far the greater portion of the total acidity was due to this volatile acid, as it is not considered that the whole of the acid was obtained by this distillation. After the distillation of the 50 cc. had been thus carried out, a small quantity

[1] Mitchell—Three Expeditions, p. 197.

of dilute sulphuric acid was added to the residue in the retort, and again distilled. The amount of acid thus obtained was very small, and not greater than would probably have been obtained if water had been added instead of sulphuric acid. It appears from this result, that no volatile acid is present in combination, but that it wholly exists in the free state.

The distillate has a very marked odour of rancid butter, and when made alkaline with soda, evaporated to dryness, and treated with sulphuric acid and alcohol, the fruity odour given by the ethyl butyrate formed by butyric acid under this treatment was very marked.

To determine the rate of distillation of this volatile acid or acids, according to the method of E. Duclaux,[1] 50 cc. were distilled in portions of 10 cc. These were then titrated separately, with the result that the first 10 cc. required 1·8 cc. of soda solution, the second 1·4 cc., the third 1·3 cc., the fourth 1·1 cc.; and if we consider that the acid remaining in the retort would require at least 1 cc., we have the following percentages :—

1st	fifth	=	27·27	per cent.	distilled.
2nd	,,	=	21·21	,,	,,
3rd	,,	=	19·70	,,	,,
4th	,,	=	16·67	,,	,,
5th	,,	=	15·15	remaining in retort.	
			100·00		

Now the rate of distillation for butyric acid does not differ very much from these percentages when we consider that only 50 cc. could be spared for experiment, while in the original determination 110 cc. were distilled in a retort holding 250 to 300 cc.

By adding together the first and second results as given in the table, of a distillation of butyric acid, so that they are represented as fifths instead of tenths, and so on throughout, we have the following figures :—

[1] Ann. Chem. Phys. [5] ii., 233.

1st	fifth	=	31·1
2nd	,,	=	25·0
3rd	,,	=	19·2
4th	,,	=	13·9
5th	,,	=	8·3

this represents 97·5 per cent. of total acids originally in the retort.

The characteristic feature of butyric acid, in distilling over in greater proportion in the first divisions of the distillate, is well marked in the results obtained from this sap, and it thus differs from acetic acid which gives less acid to the first portions of the distillate than to each succeeding one.

From a determination of the barium salt of a portion of the distillate from the sap, and weighing as $BaSO_4$ it was found that the percentage of barium sulphate was 79·2, while the theoretical quantity from barium butyrate is 74·91.

From the above results of the odour, the ethereal product, the rate of distillation, and the percentage of barium sulphate, it is apparent that the greater portion of this volatile acid is butyric acid, although the indications obtained by the result of the distillation, and also the barium determination, point to the presence of a small quantity of acetic acid.

The amount of fixed organic acid, other than the brownish humic-like material, is very small. Special effort was made to detect, if possible, the presence of malic acid, but the evidence obtainable from the small quantity of material received does not point to the presence of malic acid in the sap of *Grevillea robusta*. A very slight precipitate was obtained by adding alcohol to the prepared solution in which the absence of oxalic, tartaric, and citric acids had been determined. The usual tests with this precipitate pointed rather to the presence of succinic acid than to that of malic acid. As the acid is present in such small quantity much more material would be needed to satisfactorily determine it.

It is very evident, therefore, that the formation of the succinic acid found in the deposit in this tree, previously described, was

not from the alteration of malic acid, but rather that it was derived from the natural oxidation of butyric acid in the tree itself.

It is well known that all the fatty acids of the series $C_nH_{2n}O_2$, from butyric acid upwards, when oxidised by nitric acid yield succinic acid, together with other acids of the same series. Its formation from butyric acid is represented by the equation ($C_4H_8O_2 + O_3 = H_2O + C_4H_6O_4$).[1] Many organic substances that are oxidised to butyric acid by nitric acid, generally yield succinic acid also, notably agaricic acid, from the Larch fungus *(Boletus Laricis)*, which by oxidation with HNO_3 gives both acids.[2]

Normal butyric acid is widely distributed in the vegetable kingdom. It has been detected in croton oil, and other fatty vegetable oils; in tamarinds; in the fruits of the soap-nut tree, and that of the *Gingko biloba*, Linn.[3] Iso-butyric acid also occurs in many vegetable substances. It occurs free in the flowers of the *Arnica montana*, as well as in the Carob bean *(Ceratonia siliqua)* and among the acids of croton oil.[4]

The presence of butyric acid in rotten potatoes was demonstrated in a paper read by Mr. J. R. Rogers[5] in 1846, and from the method by which it was obtained, it must have existed as free butyric acid.

Although its presence in the vegetable kingdom is thus well authenticated, yet, I have not found that butyric acid has previously been detected in the sap of any tree.

I have no evidence as to the form in which the acid is present, whether as normal or as iso-butyric, but the odour is less unpleasant than that obtained from the decomposition of butter, so that if the sap is further investigated it may perhaps be proved to be iso-butyric acid.

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1 Watts' Dict. Chem., 1879 Edition, Vol. v., p. 453.

2 Watts' Dict. Chem., (Morley & Muir) Vol. I., p. 87.

3 Roscoe and Schorlemmer—Treatise of Chemistry, Vol. III., pt. i., p. 591.

4 *Op. cit.* p. 599.

5 Pharm. Journ. Vol. v., p. 345.

In the report of the British Association for 1868, page 475, appears a paper by Alfred R. Catton, M.A., F.R.S.E., entitled "Report of Synthetical researches on Organic Acids." From his results he arrives at the conclusion that probably the whole of the volatile acids, and a considerable part of the fixed acids, are produced by the action of nascent hydrogen on carbonic acid.

Inorganic constituents of the sap.

The amount of total solids in 100 cc. of the sap was ·5384 gram. On ignition ·1842 gram. was removed. Of the remainder ·2996 gram. was soluble in water, and ·0546 gram. insoluble. The insoluble portion consisted of the phosphates of iron, magnesium and aluminium, and of magnesia, (the solution not being saturated by CO_2), not a trace of lime could be detected in this insoluble portion.

The soluble portion consisted of the chlorides of calcium, potassium, and sodium, a trace of sulphuric acid, but not phosphoric acid; nor could a trace of magnesia be found in this portion. The chlorine was estimated by titration with nitrate of silver (1 cc. equal ·001 gram. chlorine). The alkalis were determined by estimating the chlorine in the dried mixture of their chlorides, and calculating their ratio. The calcium was determined as oxalate and weighed as carbonate.

The analysis of the inorganic constituents is as follows in 100 cc. of the sap :—

			gram.
(*a*) Insoluble portion—			
Phosphates of iron, magnesium, and aluminium	= ·0113		
Magnesia (MgO)...	= ·0386		·0546
CO_2 by difference	= ·0047		
(*b*) Soluble portion—			
Chloride of Potassium (KCl)	= ·1049		
Chloride of Sodium (NaCl)	= ·0711		·2998
Chloride of Calcium ($CaCl_2$)	= ·1174		
SO_3 = ·0036 equal to ? (Na_2SO_4) ...	= ·0064		·3544

The full analysis may be stated as follows, for 100 cc. of the sap, from which the percentage composition can be readily calculated.

Phosphates of Fe, Mg and Al. ...	= ·0113	gram.
Magnesia (MgO)	= ·0386	,,
CO_2 by difference	= ·0047	,,
Chloride of Potassium (KCl)	= ·1049	,,
Chloride of Sodium (NaCl)	= ·0711	,,
Chloride of Calcium ($CaCl_2$)	= ·1174	,,
SO_3 = ·0036 equal to ? (Na_2SO_4) ...	= ·0064	,,
Butyric Acid (by distillation)... ...	= ·1232	,,
Organic substances, organic acids, etc.	= ·1842	,,
Nitrogen	trace	,,
Water	99·6982	,,
	100·3600	

The amount of chlorine in the soluble portion was found by titration to be ·167 gram. The results of the analysis give the chlorine with the potassium as ·0499 gram., with the sodium as ·0431 gram.; while the amount of calcium found requires ·075 gram. to form the chloride, or almost the identical amount left from the alkalis. The theoretical quantity of soda has been added to the SO_3 found, although it is not certain that it is present with that base, so a query has been placed before it. The presence of phosphoric acid is well marked, also the iron, good reactions being readily obtained for both forms. Nitrogen is present, but only as a trace.

Fehling's solution shows that the sap has slight reducing properties. The absence of lithia etc. was proved by spectroscopic investigation.

In drawing conclusions from the results of this investigation of the inorganic constituents, it appears evident that the calcium in this sap was present as chloride, or in its most soluble form, and not as generally supposed as a sulphate or as a phosphate, because, not a trace of lime was found in the insoluble portion of the ignited residue. Also that the alkalis were present as chlorides.

That the magnesia is not present as a sulphate or as a chloride, because no magnesia was found in the soluble portion of the ignited residue, nor sulphuric acid in the insoluble portion ; the small amount of sulphuric acid was found in the soluble portion and was probably present in connection with the alkalis, but of this I have no evidence outside the ready solubility of the sulphate, as only small quantities of cold distilled water, repeatedly applied, were used to extract the soluble portion from the ignited residue, no heat being applied.

It appears from numerous investigations and analyses of the ash of many plants, that the elements of this class most necessary to the growth of the tree, are sulphur, phosphorus, calcium, magnesium, potassium, iron, and possibly chlorine. All of these were found existing in this sap, while in addition we find sodium, and nitrogen, the former in fair quantity, the latter only in traces. No evidence was obtained as to the form in which the nitrogen was present, or with what constituent, but nothing was precipitated on boiling the original sap. The aluminium was found to be present in only very minute quantities, thus again confirming the inert character of this abundant element. It is thus the more remarkable that such a large deposit of aluminium succinate should have accumulated in the timber as described in the paper already referred to.

The general statement that calcium is present in the form of sulphate, phosphate, or carbonate, appears to be of too broad a character, and although no doubt correct in some instances, yet, it is not so in this sap. The chemical alteration and molecular arrangement of these inorganic salts within the cells of the growing tree, is no doubt different under altered conditions, and not always the same as theoretically supposed from information obtained by artificial cultures. In the estimation of the ash after incineration, we only arrive at the extreme stage of alteration, but we do not know all the changes that have taken place during the process, or what has been the order of the molecular alteration before the completed structure of the plant was obtained.

CURRENT PAPERS, No. 2.

By H. C. Russell, B.A., C.M.G., F.R.S.

[With Plate XII.]

[*Read before the Royal Society of N. S. Wales, September 2, 1896.*]

In October 1894, I read a short paper before this Society on forty-three current papers that I had collected during the previous twelve years. The present paper contains one hundred and fifty-four collected within the past two years; many of these are important and call for publication. Twenty-three of the one hundred and fifty-four were kindly sent to me by the late Dr. Neumayer, Director up to the time of his death of the Meteorological Observatory at Hamburg. His letter stated that he thought they would be useful to me in the work I had undertaken, and they are certainly valuable contributions to the study of ocean currents about Australia. Their special interest will be pointed out presently.

I am also indebted to Capt. A. Simpson of the s.s. *Thermopylæ* for sending me copies of forty-one papers which he had himself collected. Some of these are of great local interest, and eighteen others are north of the Equator and equally valuable, but outside the area included in our chart. And to a host of other friends, some of whom will be referred to in the list which follows, and to all of whom I record my very cordial thanks for the hearty and persistent efforts which have brought together the papers which form the basis of this report. Only a small percentage of that work ever sees the light of publication, but every paper that comes to me contains valuable data about our coastal and other currents.

Out of the one hundred and fifty-four papers in the following list eighteen are outside the limits of the chart, and sixty could not be plotted either, because the track followed was so small that it would not show on this small scale chart, or because there were already too many plotted in its particular area; the remaining seventy-six papers are shown on the chart.

In my previous paper on current papers it was mentioned as an interesting fact, and it is accentuated in this one, that a large proportion of the papers which came back to me have been put into the sea a few miles from the land; in the present list forty-seven or thirty per cent of those received have made these very short journeys. In the first list, twenty-one per cent. of the papers were of the same class. As a rule papers of this class cannot be effectively plotted in a map of such small scale as this one.

To avoid mistakes, it may be stated here that the lines plotted on the chart are not intended to convey the idea that the actual tracks of the bottles are known, only two points in its journey are known: the place it was put into the sea and where it was found, the lines are simply the shortest lines to connect these two points. Neither is it supposed that the date of finding the bottle on shore is necessarily the day it landed. It is possible, nay probable, that some of them rest weeks or perhaps months before they are found. Nevertheless, in cases where a number of papers have made tracks over the same ocean their several rates of motion do not differ materially from the mean, and are much more nearly alike than one might expect them to be under the circumstances, from which it may be inferred that the bottles, as a rule, do not rest long before they are found. For instance, three papers, Nos. 157, 163 and 164, were set afloat off Cape Horn, and followed as indicated by the lines, nearly the same tracks, and their daily rates are 9·0 miles, 7·9 miles, and 10·3 miles over distances of 9,517, 8,617 and 9,585 miles. No. 163, the one that made least progress, was picked up on the western shore of the Australian

Bight in unsettled country, and Nos. 157 and 164 were found on the coast of Victoria west of Cape Otway, where probably they would not rest many days before they were found. Whereas No. 163 went ashore where there are but few residents, and presumably a bottle cast up by the sea there might rest a long time before it was found, but its daily rate seems to indicate that it did not rest very long.

In the paper I submitted in 1894 reference was made to twelve papers found on the east coast, two of these went to the south, and seven went north against the usual current, and three came in from the east. In the present list containing more than three times as many papers as the first one, we have fifteen papers found on the east coast, again three of them went to the south. Eight went to the north, and four came in from the east. In view of the well known southerly current on this coast, it is remarkable that so few of the papers found seem to go with it, and that the majority of papers found go against the current It is noteworthy that these made very slow progress, seldom exceeding one or two miles per day. One of them thrown over near Cape Howe, made a run of eight hundred and eighty miles to Moreton Bay, at an average daily rate of 1·3 miles. There is, however, no actual proof that these bottles follow the coast in going north, and in this paper there is ample proof that some papers set afloat near our southern coast go to the eastward, and are picked up on New Zealand ; there are also proofs that some papers once they get well off the coast go northward, and find a resting place on Lord Howe Island or other places. We have proof therefore, that papers starting near this coast may drift to the east, and also to the north; possibly some may go north until they get into the great easterly current which passes New Caledonia, and in this way get carried on to the Australian coast, and such a course need not have involved a greater rate of progress than three miles per day. In support of this view it may be mentioned that Nos. 160, 162, and 166, thrown over in the supposed possible track found their way on to the coast. On the

other hand twelve papers thrown over in Tasman sea found their way on to New Zealand.

In contrast with daily rate of the papers going northwards, one of these going south (No. 64) in a run of three hundred and twenty miles made 17·7 miles per day.

One very interesting paper, No. 168, was thrown into the sea in latitude 3° 50′ south, off the west coast of South America, and found its way on to the east coast of Australia in latitude 15° south, having made the journey of 8,840 miles at the rate of 9·2 miles per day; and No. 106, thrown over from the R.M.S. *Miowera* about four hundred miles to the north-east of Fiji found its way on to an island in Torres Straits at the rate of nine miles per day. Going now to the westward of Australia we find in similar low latitudes that on 2nd April, 1895, Capt. Harris of the R.M.S. *Parramatta*, coming down to Australia from Ceylon, threw over a current bottle containing No. 102, in latitude 26° 13′ south, and it was found on Farquhar Island north of Madagascar in latitude 10° 6′ south, having made the journey of 3,500 miles at the rate of 15·4 miles per day. On 19th October, 1895, Capt. Anderson of the R.M.S. *Austral*, threw over a bottle paper No. 56, which made its way on to the coast of Africa in latitude 0° 30′ south, a distance of 3,646 miles at the rate of 16·8 miles per day.

More current papers are found on the coast between Melbourne and Adelaide than on any other part of Australia. It would seem as if the bottles carried east by the current and urged by the south-west and southerly winds take a resultant direction at about east-north-east and get thrown on the coast there. Of this series many that should have been plotted here, are crowded out by the number of long distance ones and the necessarily small scale of the chart; as it is, they are almost too much crowded.

Some of these are of unusual interest, owing to the very long distances they passed over. Three, Nos. 157, 163, and 164, thrown into the sea near Cape Horn have already been referred to.

Five others in these waters, Nos. 147, 148, 165, 169, and 170, made from 9·0 to 10·7 miles per day over distances ranging from 4,400 to 5,900 miles : these are all very long runs, and they show a high velocity not found in the papers reported by me two years ago, except in those that were far south. In this paper the latitude of the quick moving ones ranges from 37° to 57° south, but there are not wanting instances of slower movement in the lower latitudes ; for instance, No. 173, starting nearly midway between South America and the Cape, made a course nearly due east 2,648 miles, landing near the Cape of Good Hope after a daily progress of 6·8 miles.

No. 158 starting in latitude 43° 15′ and longitude of the Cape of Good Hope, made a course nearly due east, and was found on the beach near Cape Otway after a journey of 6,375 miles, at the rate of 8·6 miles per day ; another, No. 180, thrown into the sea a little west of Kerguelen, found its way on to the Chatham Islands at the rate of 9·2 miles per day.

One fact may be mentioned which seems to prove that the wind has a decided action in the direction of drift : for several months in the latter part of 1895 we had very strong and frequent north-west winds, and vessels coming from the Cape of Good Hope had a similar experience ; during this period the arrival of current papers from the south coast of Australia almost ceased, while in ordinary weather they arrive very often. From this I infer that the north west winds give the current papers a set towards south of east, instead of the usual northerly set which brings them on to the south coast of Australia, and that, being thus set to the south they passed Tasmania and New Zealand to the great ocean beyond, where in all probability they sink owing to the accumulation of vegetable and other growths on the bottles.

Ref No. †	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles	Rate per day, miles	Ref. No. †
*44	Jany. 3-96	R.M.S. "Ormuz"	F. M. Tuke, Commander...	34 34 S.	114 56 E.	28 59 S.	113 58 E.	Feby. 9-96	West Coast	37	350	9·5	44
45	,, 8-96	,, ,, ...	,, ,, ...	37 55 ,,	140 20 ,,	35 35 ,,	138 45 ,,	,, 3-96	South Coast	26	180	7·0	45
46	,, 8-96	,, ,, ...	,, ,, ...	38 10 ,,	140 40 ,,	37 53 ,,	140 20 ,,	Jany. 28-96	,,	20	25	1·3	46
47	,, 8-96	,, ,, ...	,, ,, ...	38 14 ,,	140 49 ,,	37 50 ,,	140 20 ,,	,, 19-96	,,	11	30	2·7	47
48	,, 10-96	,, ,, ...	,, ,, ...	38 30 ,,	144 50 ,,	38 30 ,,	145 10 ,,	,, 15-96	,,	5	22	4·4	48
49	,, 28-96	,, ,, ...	,, ,, ...	34 0 ,,	151 15 ,,	34 0 ,,	151 10 ,,	Feby. 2-96	East Coast..	5	5	1·0	49
50	Feb. 2-96	,, ,, ...	,, ,, ...	38 30 ,,	141 30 ,,	38 28 ,,	141 35 ,,	,, 4-96	South Coast	2	14	7·0	50
51	May 13-96	,, ,, ...	,, ,, ...	38 10 ,,	140 40 ,,	38 5 ,,	140 40 ,,	May 20-96	,,	7	7	1·0	51
52	,, 13-96	,, ,, ...	,, ,, ...	38 12 ,,	140 46 ,,	38 5 ,,	140 40 ,,	June 20-96	,,	38	15	0·4	52
53	June 7-96	,, ,, ...	,, ,, ...	38 16 ,,	140 57 ,,	38 6 ,,	141 5 ,,	,, 16-96	,,	9	8	0·9	53
54	,, 10-96	,, ,, ...	,, ,, ...	35 29 ,,	136 54 ,,	34 15 ,,	137 25 ,,	July 20 96	,,	40	100	2 5	54
*55	Mar. 21-95	,, "Austral"	,, ,, ..	35 23 ,,	132 14 ,,	38 17 ,,	141 15 ,,	June 9-95	,,	80	530	6·6	55
*56	Oct. 19-95	,, ,, ...	J. F. Anderson, ,, ...	11 53 ,,	93 36 ,,	0 30 ,,	42 30 ,,	May 23-96	Indian Ocean	217	3,646	16·8	56
57	Feb. 27-96	,, ,, ...	,, ,, ...	34 14 ,,	114 36 ,,	33 36 ,,	115 22 ,,	June 7-96	South Coast	101	60	0·6	57
58	Mar. 6-96	,, ,, ...	,, ,, ...	38 37 ,,	147 32 ,,	37 47 ,,	148 8 ,,	,, 14-96	,,	100	75	0·8	58
59	Jany. 7-95	S.S. "Whampoa"	T. H. Hards Master ...	28 50 ,,	153 45 ,,	29 5 ,,	153 35 ,,	Jany. 11-95	East Coast...	4	20	5·0	59
*60	,, 8-95	,, ,, ...	,, ,, ...	25 28 ,,	153 30 ,,	27 40 ,,	153 23 ,,	Aug. 14-95	,,	218	127	0·6	60
61	Sept. 22-95	,, ,, ...	,, ,, ..	30 10 ,,	153 25 ,,	32 45 ,,	152 9 ,,	Oct. 13-95	,,	21	190	9·0	61
62	,, 26-95	,, ,, ...	,, ,, ...	33 50 ,,	151 0 ,,	35 24 ,,	150 35 ,,	Nov. 7-95	,,	42	100	2·4	62
*63	Oct. 3-95	,, ,, ...	,, ,, ...	35 38 ,,	150 39 ,,	31 33 ,,	159 6 ,,	June 6 96	,,	249	551	2·2	63
*64	,, 11-95	,, ,, ...	,, ,, ...	29 55 ,,	153 30 ,,	34 16 ,,	150 58 ,,	Oct. 29-95	,,	18	320	17·7	64
*65	May 6-95	,, "Nemesis"	J. F. Morrison, Master ...	35 10 ,,	121 1 ,,	36 50 ,,	139 40 ,,	Sept. 18-95	South Coast	135	1,054	7·8	65
66	Aug. 14-95	,, ,, ...	,, ,, ...	34 24 ,,	115 13 ,,	34 28 ,,	116 0 ,,	April 12-96	,,	241	60	0·3	66
*67	Nov. 13-95	,, ,, ...	,, ,, ...	35 18 ,,	127 53 ,,	33 40 ,,	123 40 ,,	,, 1-96	,,	140	240	1·7	67
*68	May 13-95	,, "Waihora" ...	R. Neville, Master	44 0 ,,	151 40 ,,	46 50 ,,	167 48 ,,	Mar. 18-96	New Zealand	310	850	2·7	68
*69	June 10-95	,, ,, ...	,, ,, ...	39 46 ,,	170 28 ,,	39 0 ,,	174 24 ,,	Sept. 16-95	,,	98	230	2·4	69
*70	July 31-95	,, ,, ...	,, ,, ...	45 6 ,,	159 52 ,,	40 30 ,,	175 15 ,,	Feby. 9 96	,,	193	1,020	5·3	70
*71	Feby. 9-96	,, ,, ...	,, ,, ...	38 6 ,,	165 40 ,,	35 50 ,,	173 45 ,,	July 26-96	,,	168	442	2·6	71
*72	May 30-95	,, "Rotokino"	C. Spinks, ,, ...	39 50 ,,	158 6 ,,	36 10 ,,	174 0 ,,	Nov. 24-95	,,	178	870	4·9	72
*73	June 29-95	,, ,, ...	,, ,, ...	39 45 ,,	171 51 ,,	38 35 ,,	174 37 ,,	July 17-95	,,	18	160	8·9	73
*74	,, 11-95	N.D.L. "Darmstadt" ...	M. Eichel Commander ...	22 53 ,,	178 30 ,,	19 30 ,,	169 30 ,,	Oct. 19-95	New Hebrides	130	630	4·8	74
*75	,, 11-95	,, ,, ..	,, ,, ...	19 46 ,,	177 5 W.	18 10 ,,	178 25 W.	Aug. 23-95	Fiji Group...	73	78	1·1	75
76	Oct. 25-95	R.M.S. "Arcadia"	A. C. Loggin, ,, ..	35 18 ,,	124 51 E.	34 30 ,,	118 47 E.	Mar. 2-96	South Coast	129	340	2·7	76
77	,, 27-95	,, ,, ...	,, ,, ...	33 59 ,,	114 30 ,,	33 50 ,,	114 55 ,,	July 12-96	,,	259	30	0·1	77
78	Jany. 27-96	,, ,, ...	,, ,, ..	35 56 ,,	138 20 ,,	35 36 ,,	138 30 ,,	April 14-96	,,	78	20	0·3	78
79	Nov. 3-95	S.S. "Burrumbeet" ...	A. H. Thorpe, Master ...	38 55 ,,	145 55 ,,	38 40 ,,	145 40 ,,	May 20-96	,,	199	24	0·1	79
80	Dec. 23-95	,, ,, ..	,, ,, ...	34 50 ,,	150 45 ,,	34 50 ,,	150 40 ,,	Jany. 3-96	East Coast...	11	5	0·5	80
*81	,, 29-95	,, ,, ...	,, ,, ...	38 55 ,,	145 55 ,,	37 48 ,,	148 6 ,,	,, 19-96	South Coast	21	168	8·0	81
82	Jany. 20-96	,, ,, ...	,, ,, ...	34 25 ,,	151 4 ,,	36 26 ,,	150 2 ,,	Feby. 2-96	East Coast ..	13	120	9·2	82

† Papers marked with an asterisk will be found on the Chart.

OCEAN CURRENTS.

Ref. No. †	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day miles.	Ref No. †
83	Mar. 15-96	S.S. "Burrumbeet" ..	A. H. Thorpe, Master ..	38 30 S.	149 0 E.	37 48 S.	148 38 E.	April 9-96	South Coast	25	60	2·3	83
84	June 16-95	Ship "Samuel Plimsoll" ..	John Henderson, Master ..	1 4 N	27 19 W.	11 0 N.	16 0 W.	Mar. 7 96	Atlantic ..	265	900	3·4	84
85	,, 11-96	,, ,, ...	,, ,, ...	38 43 S.	134 10 E.	38 25 S	141 30 E.	Aug. 6-96	South Coast	56	396	7·1	85
86	Feby. 8-93	Schooner "Orbost" ...	F. Limschon, Master ...	38 50 ,,	145 35 ,,	38 30 ,,	145 16 ,,	July 23-93	,,	165	25	1·5	86
87	,, 23-93	,, ,, ...	,, ,, ...	38 50 ,,	145 35 ,,	38 20 ,,	144 40 ,,	Mar. 11-93	,,	16	60	3·7	87
88	Mar. 3-93	,, ,, ...	,, ,, ...	38 50 ,,	145 35 ,,	38 20 ,,	144 40 ,,	,, 21-93	,,	18	60	3·3	88
89	,, 7-93	,, ,, ...	,, ,, ...	38 40 ,,	147 12 ,,	38 40 ,,	146 50 ,,	,, 29-93	,,	22	40	1·9	89
90	,, 8-93	,, ,, ...	,, ,, ...	38 20 ,,	147 30 ,,	38 25 ,,	147 10 ,,	,, 18-93	,,	10	20	2	90
91	July 11-93	,, ,, ...	,, ,, ...	37 33 ,,	150 2 ,,	35 52 ,,	150 0 ,,	July 18-93	East Coast...	7	45	6·5	91
92	,, 18-95	Brigantine "Ethel" ...	,, ,, ..	38 45 ,,	143 45 ,,	40 20 ,,	144 50 ,,	Oct 2-95	South Coast	76	120	1·6	92
93	Mar. 6-93	,, ,, ...	,, ,, ..	38 45 ,,	145 15 ,,	38 35 ,,	145 15 ,,	April 11-96	,,	36	10	0·3	93
94	May 10 96	,, ,, ...	,, ,, ..	38 45 ,,	143 50 ,,	38 20 ,,	144 40 ,,	June 14-96	,,	35	60	1·7	94
*95	Feby. 11-86	H.I.M.S. "Bismarck" ..	— Ascher, Commander ...	49 57 ,,	134 6 ,,	39 35 ,,	143 57 ,,	Oct 25 95	,,	3,541	530	0·2	95
*96	Dec. 29-92	S.S. "Hauroto"	R Neville, Master	49 0 ,,	171 0 ,,	33 40 ,,	174 23 ,,	Sept 22-94	New Zealand	632	300	0·5	96
*97	July 15-93	H.I.M.S. "Saida"	Lieut Noppes	35 26 ,,	153 56 ,,	27 25 ,,	153 25 ,,	Jany. 10-95	East Coast .	540	554	1·0	97
*98	Nov. 25-93	ship "Illawarra,"	——, Apprentice	49 53 ,,	155 10 ,,	36 7 ,,	174 38 ,,	Mar. 17-95	New Zealand	477	1,500	3·1	98
*99	July 17-94	,, "Saint Enoch" ...	G. G. Gordon, Master ..	44 51 ,,	151 11 ,,	36 9 ,,	173 55 ,,	‡12 months	,,	365	1,325	3·6	99
*100	Nov. 17-94	S.S. "Buteshire"	W. W. Swinton, ,, ...	34 16 ,,	176 54 ,,	35 48 ,,	174 35 ,,	Jany. 24-95	,,	68	240	3·5	100
101	Jan. 13-95	Ship "Sydney Belle" ..	J. Robinson, ,, ...	7 18 ,,	157 39 W	9 0 ,,	172 0 W	Sept. 6-95	South Pacific	236	900	3·8	101
*102	April 2-95	R.M.S "Parramatta" ...	P. Harris, Commander .	25 13 ,,	107 5 E.	10 6 ,,	51 10 E.	Nov. 16 95	Indian Ocean	228	3,500	15·4	102
*103	,, 14-95	S.S. "Rotomahana" ..	W. Waller, Master... ...	44 25 ,,	153 41 ,,	41 45 ,,	171 25 ,,	Feby. 6-96	New Zealand	298	1,080	3·6	103
104	,, 26 95	,, "Southern Cross" ...	A. Child, ,, ...	11 28 N.	75 2 ,,	7 30 N	79 45 ,,	May 21-95	India ...	25	360	14·4	104
*105	June 13-95	,, "Gulf of Bothnia" .	T. G. M. Ligertwood, ,,	37 30 S.	131 58 ,,	37 58 S.	140 30 ,,	Sept. 29-95	South Coast	108	467	4·3	105
*106	,, 28-95	R.M.S. "Miowera" ...	J. Stott, Commander ...	9 8 ,,	175 4 W.	10 0 ,,	142 0 ,,	May 24-96	South Pacific	331	2,967	9·0	106
107	Aug. 3-95	M.M. "Armand Behic" ..	— Poydenot, ,, ...	35 39 ,,	131 52 E.	38 10 ,,	141 20 ,,	Sept. 11-95	South Coast	39	538	13·8	107
108	Sep. 18-95	R.M.S. "Orotava"	J. Linklater, ,, ...	38 6 ,,	140 36 ,,	38 5 ,,	141 55 ,,	Nov. 5-95	,,	48	75	1·5	108
*109	Dec. 2-95	,, "Warrimoo" ...	C. E. Bird, R.N.R. Comd ..	11 12 ,,	176 15 W.	Fiji	Group	May 17-96	South Pacific	167	448	2·7	109
*110	Jan. 4-96	Barque "Leucadia" ...	John Hutchinson, Master	11 30 ,,	175 28 E.	20 20 S.	169 50 E.	,, 6-96	,,	123	724	5 9	110
111	Mar. 16-96	R.M.S. "Rome"	A. B. Darnell, Commander	40 5 ,,	147 10 ,,	40 10 ,,	147 55 ,,	Mar. 30-96	South Coast	14	53	3·5	111
*112	,, 6-96	S.S. "Hawkes Bay" ...	J. C. Felgate, Master	49 1 ,,	140 8 ,,	37 48 ,,	148 37 ,,	July 28-96	,,	144	511	3·5	112
*113	May 21-96	R.M.S "Victoria"... .	W. D. G. Worcester, Com.	35 36 ,,	132 11 ,,	37 5 ,,	139 48 ,,	,, 19-96	,,	59	448	7·6	113
114	June 20 96	S.S. "Memmuir"	H. Craig, Master . . .	38 30 ,,	147 47 ,,	38 17 ,,	147 20 ,,	,, 31-96	,,	41	27	0·7	114
115	Aug. 3-96	,, "Guthrie"	St. John George, Master .	29 2 ,,	153 30 ,,	29 0 ,,	153 28 ,,	Aug. 6-96	East Coast ..	3	3	1·0	115
116	Aug. 29-88	S.S. "Australasian" .	Alexr. Simpson, Master ..	39 10 ,,	142 11 ,,	38 13 ,,	142 23 ,,	Sept. 23-88	South Coast	25	50	2·0	116
117	Mar. 17-89	,, ,, ...	,, ,, ...	40 11 ,,	139 46 ,,	38 20 ,,	142 2 ,,	not given	,,	...	180	...	117
*118	April 14-8	,, ,, ..	,, ,, ...	31 6 ,,	113 49 ,,	32 30 ,,	115 45 ,,	July 21-89	West Coast	98	235	2·4	118
119	,, 30-89	,, ,, ..	,, ,, ...	3 45 N.	100 11 ,,	3 20 N.	101 10 ,,	May 10-89	Malacca Str.	10	70	7·0	119
120	,, 30-89	,, ,, ...	,, ,, ...	3 45 ,,	100 11 ,,	5 30 ,,	100 15 ,,	June 7-89	,,	38	120	3·2	120
121	May 2-89	,, ,, ..	,, ,, ...	12 34 ,,	94 42 ,,	12 15 ,,	98 30 ,,	Aug. 24-89	Bay of Bengal	114	270	2·4	121

† Papers marked with an asterisk will be found on the Chart. ‡ Nearly 12 months.

Ref No. †	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day, miles.	Ref. No. †
122	May 19-89	S.S. "Australasian" ...	Alexr. Simpson, Master ...	6 4 N	80 6 E.	6 36 N.	79 58 E.	not given	Indian Ocean	...	30	...	122
123	,, 27-89	,, ,, ...	,, ,, ...	11 57 ,,	55 28 ,,	16 50 ,,	96 15 ,,	18 months	Bay of Bengal	3,200	...	...	123
*124	Sept. 29-89	,, ,, ...	,, ,, ...	37 13 S.	150 7 ,,	40 45 S.	175 15 ,,	Nov. 4-90	New Zealand	401	1,345	3·4	124
125	Oct. 1-89	,, ,, ...	,, ,, ...	38 40 ,,	142 20 ,,	38 50 ,,	143 35 ,,	Mar. 10-92	South Coast	890	85	0·1	125
*126	,, 11 89	,, ,, ...	,, ,, ...	35 31 ,,	122 43 ,,	38 10 ,,	141 10 ,,	Feby. 14 91	,,	490	995	2·0	126
127	Nov. 14-89	,, ,, ...	,, ,, ...	40 26 N.	9 35 W.	33 13 N.	8 30 W.	May 21-90	N. Atlantic	188	518	2·8	127
128	Dec. 15-89	,, ,, ...	,, ,, ...	40 19 ,,	11 51 ,,	26 40 S.	15 12 E.	not given	,,	...	4,760	...	128
129	,, 16-89	,, ,, ...	,, ,, ...	35 25 ,,	13 42 ,,	33 0 N.	16 30 W.	Jan. 16-90	,,	31	195	6·3	129
130	,, 23-89	,, ,, ...	,, ,, ...	5 6 ,,	14 2 ,,	6 15 ,,	4 40 E.	Mar. 5-90	Atlantic ...	72	1,300	18·1	130
131	Jan. 23-90	,, ,, ...	,, ,, ...	39 14 S.	142 40 E	36 55 S.	139 40 ,,	Oct. 13-90	South Coast	263	220	0·8	131
132	Feby. 11-90	,, ,, ...	,, ,, ...	37 1 ,,	150 2 ,,	37 15 ,,	150 0 ,,	Feby. 16-90	East Coast ..	5	15	3·0	132
133	,, 15 90	,, ,, ...	,, ,, ...	38 42 ,,	142 26 ,,	38 20 ,,	141 40 ,,	Mar. 6-90	South Coast	19	34	1·9	133
*134	June 23-90	,, ,, ...	,, ,, ...	41 19 ,,	127 15 ,,	38 47 ,,	143 25 ,,	Jany. 10-91	,,	201	848	4·2	134
135	July 2-90	,, ,, ...	,, ,, ...	37 58 ,,	149 17 ,,	40 0 ,,	147 45 ,,	Mar. 30-92	,,	636	120	0·2	135
*136	Aug. 3-90	,, ,, ...	,, ,, ...	19 5 ,,	147 15 ,,	15 20 ,,	145 40 ,,	April 12-91	East Coast ..	252	330	1·3	136
137	Sept. 29-90	,, ,, ...	,, ,, ...	38 37 ,,	142 27 ,,	38 42 ,,	143 10 ,,	Oct. 15-90	South Coast	16	37	2·3	137
*138	Mar. 24-91	,, ,, ...	,, ,, ...	43 5 ,,	131 50 ,,	38 47 ,,	143 25 ,,	‡12 months	,,	365	626	1·7	138
139	,, 25-91	,, ,, ...	,, ,, ...	40 50 ,,	137 58 ,,	38 18 ,,	142 0 ,,	Nov. 5-91	,,	225	294	1·3	139
*140	May 1-91	,, ,, ...	,, ,, ...	35 10 ,,	110 36 ,,	34 45 ,,	118 30 ,,	Mar. 15-91	,,	...	369	...	140
141	April 26-91	,, ,, ...	,, ,, ...	38 26 ,,	141 26 ,,	38 5 ,,	141 0 ,,	June 21-91	,,	56	45	0·8	141
142	May 16-91	,, ,, ...	,, ,, ...	34 10 ,,	25 17 ,,	Cape of	Good Hope	‡7 weeks	C. Good Hope	...	...	...	142
143	June 9-91	,, ,, ...	,, ,, ...	50 30 N.	1 22 W.	50 47 N.	0 4 E.	July 8-91	Eng. Channel	29	59	2·0	143
144	,, 9-91	,, ,, ...	,, ,, ...	50 30 ,,	1 22 ,,	50 47 ,,	0 2 ,,	no date	,,	...	59	...	144
145	,, 9-91	,, ,, ...	,, ,, ...	50 30 ,,	1 22 ,,	50 45 ,,	0 10 ,,	July 4-91	,,	25	66	2·6	145
*146	July 20-92	,, ,, ...	,, ,, ...	35 21 S.	120 23 E.	33 40 S.	122 45 ,,	Mar. 30-93	South Coast	253	198	0·8	146
*147	Oct. 22-92	,, ,, ...	,, ,, ...	45 10 ,,	59 24 ,,	33 25 ,,	134 45 ,,	Jany. 22-94	South. Ocean	457	4,081	9·0	147
*148	92	,, ,, ...	,, ,, ...	46 20 ,,	53 0 ,,	37 0 ,,	139 40 ,,	‡13 months	,,	390	4,557	11·7	148
*149	March 93	,, "Thermopylæ" ...	,, ,, ...	36 25 ,,	150 5 ,,	36 12 ,,	175 20 ,,	Jany. 21-95	New Zealand	660	1,456	2·2	149
*150	April 7-93	,, ,, ...	,, ,, ...	39 7 ,,	146 30 ,,	33 40 ,,	151 20 ,,	Mar. 18-94	East Coast ..	345	476	1·4	150
151	Sept. 27-93	,, ,, ...	,, ,, ...	36 54 N	12 57 W.	35 10 N.	6 8 W.	Jany. 25-94	N. Atlantic	120	510	4·3	151
*152	May 18-94	,, ,, ...	,, ,, ...	33 0 S.	36 0 E	29 50 S.	31 0 E.	Oct. 2-94	C. Good Hope.	137	325	2·4	152
153	July 31-94	,, ,, ...	,, ,, ...	11 18 N.	17 13 W.	locality not given		Aug. 14-94	N. Atlantic	14	...	...	153
154	,, 31 94	,, ,, ...	,, ,, ...	11 18 ,,	17 13 ,,	,,	,,	,, 14-94	,,	14	...	...	154
*155	Oct. 27-94	,, ,, ...	,, ,, ...	33 11 S	26 48 E.	33 14 S	27 30 E.	Nov. 3-94	C. Good Hope	7	40	5·7	155
*156	Mar. 5-95	,, ,, ...	,, ,, ...	37 2 ,,	131 47 ,,	36 42 ,,	139 42 ,,	Sept. 21-95	South Coast	200	450	2·3	156
		The following twenty-three papers were forwarded by the late Dr. Neumayer, of the Deutsche Seewarte Hamburg.											
*157	July 14-64	Ship "Norfolk"	— Tonkin, Master	56 40 S.	66 16 W.	38 20 S.	142 11 E.	June 9-67	South. Ocean	1,060	9,517	9·0	157
*158	Mar. 5-83	"Levuka"	A. Hanse, ,, ...	43 15 ,,	18 10 E.	38 37 ,,	142 53 ,,	Mar. 12-85	,,	738	6,375	8·6	158
*159	Dec. 4-84	"Peter Godeffroy" ...	J. Möller, ,, ...	43 12 ,,	120 30 ,,	39 35 ,,	143 57 ,,	June 29-85	South Coast	207	1,236	6·0	159

† Papers marked with an asterisk will be found on the Chart. ‡ Only approximate.

OCEAN CURRENTS.

Ref. No. †	Date when put into the sea.	Name of Ship.	Name.	Thrown Over. Lat. ° ′	Thrown Over. Long. ° ′	Where Found. Lat. ° ′	Where Found. Long. ° ′	Date when Found.	Locality.	Interval Days.	Estimated distance in miles.	Rate per day miles.	Ref. No. †
*160	Mar. 23-84	Ship "Canopus"	B. Loose, Master	27 47 S.	175 46 E.	29 15 S.	153 24 E.	May 25-85	East Coast...	428	1,375	3·2	160
*161	Nov. 14-87	"Luna"	R. Henricksen, Master .	43 0 ,,	127 10 ,,	38 38 ,,	143 0 ,,	,, 3-88	South Coast	171	877	5·1	161
*162	May 2-88	"Amelia"	F. Warneke, ,, ...	38 30 ,,	150 30 ,,	26 3 ,,	153 9 ,,	Mar. 22-90	East Coast...	689	880	1·3	162
*163	April 21-88	"Werner"	J. Herdorff, ,, ...	57 6 ,,	65 29 W.	33 53 ,,	123 0 ,,	April 20-91	South. Ocean	1,094	8,617	7·9	163
*164	Mar. 23-90	"Kosciusko"	R. Odegaard, ,, ...	57 25 ,,	70 48 ,,	38 4 ,,	140 42 ,,	Oct. 12-92	,,	934	9,585	10·3	164
*165	Dec. 8-90	"Selene"	O. Schmidt, ,, ...	44 19 ,,	41 30 E.	33 51 ,,	121 20 ,,	Jany. 14-93	,,	767	4,399	5·7	165
*166	,, 21-90	H.I.M.S. "Sophie" ..	Commander	17 20 ,,	176 25 ,,	28 32 ,,	153 34 ,,	April 14-92	East Coast...	470	1,688	3·6	166
*167	Jany. 11-92	S.S. "Habsburg"	W. Schmolder, Master ...	35 47 ,,	129 30 ,,	33 22 ,,	124 0 ,,	Mar. 26-92	South Coast	75	373	5·0	167
*168	Feby. 5-92	Ship "J. H. Leibken" ..	E. J. Schoone, ,, ...	3 52 ,,	85 38 W.	15 44 ,,	145 27 ,,	Sept. 28-94	South Pacific	964	8,840	9·2	168
*169	Mar. 8-92	Barque "Speculant" ...	O Kampehl, ,, ...	39 52 ,,	52 25 E.	38 0 ,,	140 30 ,,	Aug. 3-93	South. Ocean	513	4,779	9·3	169
*170	July 25-92	"Peter Rickmers" ...	H. Andersen, ,, ...	36 0 ,,	21 10 ,,	32 20 ,,	126 0 ,,	April 23-94	,,	637	5,970	9·4	170
*171	May 22-93	S.S. "Elberfeld"	C. Sass, ,, ...	36 48 ,,	133 48 ,,	40 0 ,,	144 7 ,,	Dec. 20-93	South Coast	212	601	2·8	171
*172	Sept. 20-93	,, "Salier"	A. Konemann, ,, ...	35 40 ,,	133 0 ,,	35 44 ,,	137 58 ,,	,, 2-93	,,	73	230	3·2	172
*173	Aug. 9 92	Barque "Primus"	B. Reumann, ,, ...	42 0 ,,	31 34 W.	Caledon	S. Africa	Sept. 1-93	South Africa	388	2,648	6·8	173
174	Nov. 27-92	H.I.M.S. "Sperber" ...	Lieut. S. Schafer	3 36 N.	170 2 E.	8 51 N.	170 49 E.	April 24-93	North Pacific	148	360	2·4	174
*175	Jany. 24-93	Ship "Palmyra"	G. Schlüter, Master ...	1 22 S.	30 16 W.	0 42 S.	47 7 W.	Mar. 29-93	Brazil ...	64	1,190	18·6	175
*176	Mar. 31-93	S.S. "Tijuca"	H. Langerhanufz, Master...	8 55 ,,	34 49 ,,	9 10 ,,	35 18 ,,	April 5-93	,, ...	5	35	7·0	176
*177	June 4-93	,, ,, ...	,, ,, ...	7 9 ,,	34 20 ,,	2 17 ,,	43 20 ,,	Oct. 5-93	,, ..	123	760	6·2	177
*178	Aug. 14 93	Barq. "Gustavo Adolpho"	F. Tiemann, ,, ..	14 30 ,,	33 55 ,,	17 32 ,,	39 11 ,,	,, 6-93	,, ...	53	425	8·0	178
*179	Sept. 10-92	S.S. "Olinda"	J. Bruhn, ,, ..	20 56 ,,	39 42 ,,	20 57 ,,	40 48 ,,	,, 21-93	,, ...	41	68	1·7	179
*180	Oct. 9-94	,, "Port Hunter" ..	S. M. Orr, ,, ..	45 20 ,,	63 59 E.	44 0 ,,	177 0 W.	July 16-96	South. Ocean	645	5,905	9·2	180
181	Aug. 1-96	,, "Tsinan"	George Ramsay, ,, ..	38 50 ,,	145 25 ,,	38 45 ,,	146 15 E.	Aug. 15-96	South Coast	14	50	3·6	181
182	,, 7-96	,, ,, ...	,, ,, ..	38 31 ,,	144 52 ,,	38 30 ,,	145 8 ,,	Sept. 6-96	,,	30	15	0·5	182
*183	Feby. 4-96	,, "Rotokino"	C. Spinks, ,, ...	40 10 ,,	160 10 ,,	34 45 ,,	172 45 ,,	Aug. 23-96	New Zealand	201	630	3·1	183
*184	April 5-96	Ship "Aristides"	W. S. Poppy, ,, ...	35 29 ,,	151 47 ,,	32 48 ,,	152 9 ,,	May 26-96	East Coast ...	51	210	4·1	184
185	May 17-96	R.M S. "Ormuz"	F. M. Tuke, Commander...	35 16 ,,	150 55 ,,	35 14 ,,	150 30 ,,	,, 29-96	,,	12	27	2·3	185
186	Aug. 9-96	,, "Australia" ...	J. Reeves, ,, ...	37 39 ,,	139 46 ,,	37 35 ,,	140 0 ,,	Sept. 6-96	South Coast	28	20	0·7	186
187	Dec. 21-90	,, "Orotava"	G. N. Conlan, ,, ...	34 53 ,,	115 42 ,,	34 27 ,,	115 46 ,,	,, 12-94	,,	1,361	25	...	187
188	June 14-94	,, ,, ...	R. L. Routh, ,, ...	7 15 N.	77 48 ,,	9 0 N.	79 50 ,,	July 2-94	Ceylon ...	18	160	8·9	188
189	,, 6-96	S.S. "Thermopylæ" ...	Alexr. Simpson, Master ..	37 42 S.	135 10 ,,	36 50 S	139 52 ,,	Sept. 21-96	South Coast	107	275	2·6	189
*190	May 7-96	,, "Tsinan"	George Ramsay ,, ..	19 7 ,,	147 20 ,,	17 50 ,,	146 18 ,,	,, 11 96	East Coast..	127	120	0·8	190
*191	,, 29-95	,, "Rotokino"	C. Spinks, ,, ...	42 34 ,,	161 33 ,,	35 45 ,,	173 35 ,,	Dec. 8-95	New Zealand	193	795	4·1	191
*192	June 7-95	,, "Port Stephens" ...	R. Whitehead ,, ..	16 9 ,,	176 51 ,,	13 30 ,,	167 20 ,,	Sept. 15-95	South Pacific	100	635	6·4	192
*193	Aug. 26-95	C.S. "Sherard Osborne"...	C. O. Mage, Commander	37 40 ,,	163 23 ,,	39 10 ,,	174 10 ,,	Dec. 14-95	New Zealand	110	546	5·0	193
*194	Sept. 17-95	Ship "Patriarch"	Mark Breach, Master .	40 53 ,,	118 52 ,,	40 0 ,,	143 50 ,,	June 7-96	South Coast	264	1,300	4·9	194
*195	Dec. 2-95	S.S. "Port Melbourne" ...	M.W.C. Hepworth, Master	37 54 ,,	133 50 ,,	32 13 ,,	126 20 ,,	Aug. 10-96	,,	252	490	1·9	195
*196	June 22-96	R.M.S. "Cuzco"	H. W. Livett, Commander	35 42 ,,	133 0 ,,	36 0 ,,	139 40 ,,	Sept. 14-96	,,	84	390	4·6	196
197	Sept. 12-96	S.S. "Elingamite"	A. H. Thorpe, Master ...	38 30 ,,	148 0 ,,	37 48 ,,	148 40 ,,	,, 27 96	,,	15	60	4·0	197
*198	Feby. 27-95	,, "Thermopylæ" ...	Alex Simpson ,, ..	39 45 ,,	146 54 ,,	33 10 ,,	151 38 ,,	Oct. 11-96	East Coast..	591	550	1·0	198
*199	Aug. 23-96	R.M.S. "Ophir"	J. F. Ruthven, Commander	32 57 ,,	112 58 ,,	32 3 ,,	115 45 ,,	,, 11-96	West Coast	49	170	3·5	199
*200	July 16-96	Ship "Derwent"	J. R. Andrew, Master ...	39 28 ,,	138 8 ,,	38 0 ,,	140 30 ,,	,, 19-96	South Coast	95	145	1·5	200

† Papers marked with an asterisk will be found on the Chart.

ADDITIONAL REMARKS CONCERNING ABORIGINAL BORA HELD AT GUNDABLOUI IN 1894.

By R. H. MATHEWS, Licensed Surveyor.

IN 1894 I contributed to the Royal Society of New South Wales a paper describing a Bora,[1] which took place at Gundabloui, on the Moonie River, in the colony just named. As stated in that paper,[2] the information from which it was prepared was obtained from a correspondent residing at Mogil Mogil, about fifteen miles from Gundabloui. Although this gentleman gave me his assistance very willingly, he was altogether unaccustomed to the fulness of detail necessary in original research of this character, and was therefore unable to satisfy me in reference to certain parts of the ceremonies. There was the further disadvantage of my correspondent being separated from me by upwards of five hundred miles, which caused much delay and difficulty in obtaining answers to my questions. From my knowledge of the initiation ceremonies of other tribes,[3] I considered that the statements furnished to me were substantially correct, and I had either to accept them as they were, or abandon the idea of publishing the results of my enquiries altogether. As no one had previously attempted to give a connected account of the Bora of the Kamilaroi tribes, and knowing that further details could be supplied in the form of a supplementary article at any time, I determined to prepare a paper from the mass of original information which I had collected.

As the subject of the initiation ceremonies of the Australian tribes was then very little understood either in Australia or in England, I also sent a summarized copy of that paper to the

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[1] Journ. Roy. Soc. N. S. Wales, XXVIII., 98 – 129. [2] *Loc. cit.* 105 – 106.

[3] "The Burbung of the Wiradthuri Tribes"—Journ. Anthrop. Inst., XXV., 295 – 318. "The Initiation Ceremonies of the Aborigines of the Upper Lachlan"—Proc. Roy. Geog. Soc. Aust. (Q.) XI., 167 – 169. "The Burbung of the New England Tribes"—Proc. Roy. Soc. Victoria, IX., (N.S.), 120 – 136.

Anthropological Institute of Great Britain,[1] in order that the subject might be prominently brought before the members of that body, for comparison with the initiation ceremonies in other countries. Being desirous of making my description of the Bora as complete and accurate as possible, I then determined to travel into the district in which it took place, and make personal enquiries among the tribes who had been present at it. From the comprehensive particulars gathered by me direct from the natives on that occasion, I forwarded to the Anthropological Institute a second paper,[2] supplying some omissions, and correcting some inaccuracies of detail, which had been made in my former memoir. The two papers referred to in this paragraph taken together, contain a complete narrative of everything which took place in connection with the Bora held at Gundabloui.

There still remains the further duty of correcting the account of that Bora which was published in this Journal.[3] With regard to the statement of Mr. J. A. Glass, at p. 103, that a half-caste named Billy Clark was allowed the option of either having a front tooth knocked out, or eating human ordure, I am now satisfied, from enquiries which I have since made from old blackfellows at Gundabloui, that Billy Clark was not initiated. These old men told me that in those days, some thirty or forty years ago, half-castes were not allowed to go through the Bora ceremonies—that innovation having crept in after the half castes became numerous. They further told me that there was no option, and if any novice had persisted in refusing to eat what was offered to him or to have his tooth extracted the *kooringal* would have killed him on the spot.

The following lines should be struck out: At p. 107, all the words commencing with "which" in line 6 to the word "headman" in line 14; also from the word "and" in line 29 to the

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[1] Journ. Anthrop. Inst., XXIV., 411–427.

[2] *Op. cit.*, XXV., 318–339.

[3] Journ. Roy. Soc. N. S. Wales, XXVIII., 93–129.

word "arranged" in line 4 on page 108. At p. 109, from the word "and" in line 16 to the word "top" in line 18. At p. 114, from the word "Every" in line 29 to the end of page 115. At p. 116, from the word "the" in line 23 to the word "ring" in line 14 on page 117. Also at p. 117, from the word "As" in line 19 to the end of page 118. At p. 119, from the word "After" in line 10 to the word "circle" in line 1 on p. 120. Also at p. 120, from the word "During" in line 25 to the word "hunt" in line 28; and the words "and boys" in line 34. At p. 121, lines 3 to 16 inclusive. At p. 122, lines 15 to 18 inclusive. At p. 123, from the word "The" in line 8 to the word "come" in line 1 on page 124.

When the foregoing corrections have been made in the paper contributed to the Royal Society of New South Wales, the student is recommended to peruse it in conjunction with my second memoir on the Bora[1] communicated to the Anthropological Institute of Great Britain, when the two articles, read side by side, will be found to contain a compendious account of the Gundabloui Bora. Another Bora, which took place at Tallwood, Queensland, is described in a paper contributed by me to the Royal Society of Victoria,[2] which contains much important additional information respecting the initiation ceremonies of the Kamilaroi tribes.

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[1] Journ. Anthrop. Inst., xxv., 318–339.

[2] Proc. Roy. Soc. Victoria, ix., (N.S.), 137–173.

On the OCCURRENCE of PRECIOUS STONES in NEW SOUTH WALES, and the DEPOSITS in which they are found.

By Rev. J. Milne Curran.

[With Plates XIII.–XX.]

[*Read before the Royal Society of N. S. Wales, October 7, 1896.*]

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Introduction.

Gems were discovered in New South Wales when gold was found by Hargraves at Summer Hill Creek near Ophir. In the rush that followed, little was thought of the coloured stones that remain almost to the last in the cradle or the prospecting dish. Not long ago I had an opportunity of speaking with one of the Toms, who were associated with Hargraves, and I was assured that even in the early days many of the diggers collected gem-

stones, but only coloured stones were considered of any value, as the diamond was not even thought about. Gradually more interest was taken in the matter, for in the year 1860, the Rev. W. B. Clarke wrote an appendix to his "Southern Goldfields," entitled "New South Wales a Diamond Country." At the date of writing a long list of gems are recorded as being found in this country, from the diamond, the king of precious stones, to the noble opal, which might aptly be called the queen of gems.

From a commercial standpoint, precious stones may not have added much to the wealth of the country. None of the diamond mines have realised the high promise they once gave of a great industry. But we may safely say that New South Wales now produces the finest noble opal in the world.

In dealing with the precious stones of the Colony, as this paper is based for the most part on the writer's own observations, I do not propose to incorporate all the long lists of localities where gems are found, as given in Professor Liversidge's valuable work on the Minerals of New South Wales. I propose to touch only on the places where I have some personal knowledge of the occurrence of gems and precious stones. In one or two instances some ten years have elapsed since I made my notes, but I have taken care that no new interpretation of facts has escaped notice. I may add that the photographs that illustrate the paper are original, and are now issued for the first time.

Previous Observers.

1851. Diamond from the Turon identified by Stutchbury—Papers Relative to Geological Surveys, New South Wales, 1851, p. 39.

1851. Topaz, Ruby, Garnet, Sapphire identified by Stutchbury—Ibid, p. 38.

1860. New South Wales a Diamond Country, Appendix C. to Southern Gold Fields, Rev. W. B. Clarke—Sydney, Reading and Wellbank.

1870. Discovery of Diamonds in New South Wales, Rev. W. B. Clarke. Annual Address to the Royal Society—Trans. Roy. Soc. N.S.W., 1870, p. 6, (1871).

1870. Clarke receives Diamonds from Kangaloon—Trans. Roy. Soc. N.S.W., 1870, p. 8.

1870. On the occurrence of the Diamond near Mudgee, Norman Taylor and Dr. A. M. Thomson—Trans. Roy. Soc. N.S.W., 1870, p. 94.

1872. Localities for Diamonds in New South Wales, enumerated by Rev. W. B. Clarke in his Anniversary Address to the Royal Society of New South Wales—Trans. Roy. Soc. N.S.W. p. 12, (1873).

1872. On Australian Gems, by George Milner Stephen—Trans. Roy. Soc. N.S.W., 1872.

1873. Note on the Bingara Diamond District, by Archibald Liversidge—Trans. Roy. Soc. N.S.W., 1873, p. 91. This paper has been reprinted in Prof. Liversidge's 'Minerals of New South Wales.'

1874. Minerals of New South Wales, by A. Liversidge—Trans. Roy. Soc. N.S.W., 1874.

1875. Gem Stones, by C. S. Wilkinson—Mines and Mineral Statistics of N. S. Wales, p. 103, Sydney, Government Printer, 1875.

1879. On the Cudgegong Diamond Field, N. S. Wales, Norman Taylor—Geological Magazine, 1879, pp. 399 and 444.

1881. Report on Bingara and Ironbark Goldfield, by E. F. Pittman—Annual Report Department of Mines, New South Wales, 1881, p. 141, (1882).

1886. Report on New South Wales Diamonds, by Thos. Davies and R. Etheridge, Junr.—Annual Report of the Department of Mines, N. S. Wales, 1886, p. 42, (1887).

1887. Geological Examination of the Diamond-bearing Formations in the Inverell District, by C. S. Wilkinson—Annual Report of the Department of Mines, N. S. Wales, 1887, p. 141, (1887-8).

1887. Diamonds and other Gems in New South Wales, by Harrie Wood—Mineral Products of N. S. Wales, p. 43, Sydney, Government Printer, 1887.

1887. Minerals of New South Wales, by A. Liversidge—London Trübner and Co.

1889. Diamonds and other Gems of New South Wales, by J. E. Carne—Records of the Geological Survey of N. S. Wales, Vol. I., p. 93.

1890. Note on the Mittagong Diamond Mine, C. S. Wilkinson—Annual Report of the Department of Mines, N. S. Wales, p. 210.

1891. Report on the Discovery of Emeralds in the Vegetable Creek District, T. W. E. David—Annual Report Department of Mines, 1891, p. 229 (1892).

1892. Notes on the occurrence of Opal in New South Wales, by William Anderson—Records of the Geological Survey of N. S. Wales, Vol. III., p. 29.

1892. Report on the White Cliffs Opal Field, by John B. Jaquet—Annual Report of the Department of Mines, N. S. Wales, 1892, p. 142, (1893).

1893. Notes on Bingara Diamond Field, by Rev. J. Milne Curran Exhibit of Diamonds—Journ. Roy. Soc. N. S. Wales, Vol. XXVIII., 1893, p. 480.

1893. On a Sand from Bingara, by George W. Card.—Records of the Geological Survey N. S. Wales, Vol. III., p. 3.

1893. Note on Diamond Mine near Mittagong, by Edwd. F. Pittman, Government Geologist—Annual Report Department of Mines, N. S. Wales, 1893, p. 102, (1894).

1894. Olivine from Gum-flat Road, four miles from Inverell, one inch in diameter. Garnet, *not* waterworn, near Bingara, (Almandite) on basalt hill. D. A. Porter—Journ. Royal Society, N. S. Wales 1894, Vol. XXVIII., p. 40.

1894. Report on Bingara Diamond Fields, by Geo. A. Stonier—Annual Report Department of Mines, N. S. Wales, 1894, p. 131. Issue 1895.

1894. On Almandine Garnet from the Hawkesbury Sandstone at Sydney, by Henry G. Smith—Journ. Royal Society N.S. Wales, Vol. XXVIII., p. 47.

1894. Notes on occurrence of Diamonds at Bingara, by G. A. Stonier—Records of the Geological Survey of New South Wales, Vol. IV., p. 51.

1895. Note on Gem Sand from the Oberon District, by G. W. Card—Records Geological Survey of New South Wales, Vol. IV., p. 132. (Sapphire, Zircon.)

DIAMOND.

Diamonds were discovered in this Colony by Mr. Stutchbury, the Government Geologist, and by Mr. E. H. Hargraves, in the year 1851.[1] The Rev. W. B. Clarke had many diamonds brought to him in 1859 and 1860.[2]

Systematic search for diamonds was begun in 1869 on the Cudgegong River at Warburton, better known as Two-Mile-Flat. Some very fine stones were obtained here, but the industry was not a profitable one, and in 1890, the date of my visit to the locality, there was not a single man engaged in Diamond-mining. The few miners who, to this date, are working the Tertiary and Post-Tertiary drifts for gold, occasionally find a good diamond. The geology of the Cudgegong Diamond-field has been described in detail by Messrs. Norman Taylor and Thomson,[3] and later by Mr. Taylor in the Geological Magazine.[4]

No stones hitherto found in Australia have surpassed the diamonds from this locality. The yield per load has been greater

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[1] Liversidge—Minerals of New South Wales, p. 116. Mr. Stutchbury reported in 1851 that he saw a "beautifully crystallized diamond from the Turon River."—Papers Relative to Geological Surveys, New South Wales. Laid upon the Council Table 2nd December, 1851. The Report is dated "Camp near Burrondong, Oct. 18th, 1851," and by an evident clerical error, is not included in the schedule prefixed to the papers.

[2] Southern Goldfields, p. 272.

[3] Trans. Roy. Soc. N. S. Wales, 1870, p. 94.

[4] Geological Magazine, 1879, pp. 399 and 444.

at Bingara, but the stones are on the whole smaller and show a higher percentage of "off" colour.

Summarised, geological conditions of the Cudgegong Diamond-field are simple enough. A river valley in Palæozoic rocks, with its alluvial deposits, is covered by a sheet of basalt. This basalt is again cut through, forming a newer valley and redistributing the drifts of the older. The older drift is believed to be Pliocene. The redistributed drifts are Pleistocene and recent. Diamonds are found in the older drift underlying the basalt, and in the redistributed drifts.

Bingara.—The conditions under which the diamond is found at Bingara are somewhat similar. The geology of Bingara has been described by Liversidge, Wilkinson, Pittman, and Stonier. The various papers are enumerated in the list of previous observers. Shortly, it may be described as an area occupied by carboniferous clay-stones, much faulted and broken, serpentine, basalt, and Tertiary and Pleistocene drifts. Diamonds have been found in the drifts only. These drifts are in places resting on the claystones and covered by basalt. Patches of the same drifts occur where the capping of basalt has been denuded, and it is in areas of this class that the greatest quantity of diamonds have been found. The "Monte Christo" mine is a case in point. Here the "wash" has been denuded of its basaltic covering and possibly redistributed. The surface of the wash is cemented to a hard iron-stained crust. Some phenomenal yields of diamonds have been recorded from this mine. During my visit, Captain Rodgers washed a hundred weight of the drift and got twenty-nine diamonds. The gems were small, about three to a carat, and nearly half were of a straw colour.

I measured the following section at a depth of forty feet :—

1. Four inches of a wash, of pebbles under half-an inch in diameter. Clear white and black quartz pebbles, and tourmaline showing. Contains diamonds.

2. Four feet of wash with pebbles up to three inches in diameter. This has gem-sand, but no diamonds.

3. One foot of wash separated from No. 2 by a stratum of sand. This has a good run of diamonds.

4. Bedded sediment under which another wash is known to carry diamonds.

The wash was becoming more friable at a depth, being hardest near the surface.

Tourmaline was in every instance present when diamonds were found. I brought away a hundred weight of the Bingara wash, and on examination noted the following minerals and rocks:—1. Tourmaline. 2. Sapphire. 3. Spinellé. 4. Topaz. 5. Garnet. 6. Quartz. 7. Slate. 8. Claystone. 9. Concretionary Ironstone.

I made a calculation based on several parcels as to the percentage of good diamonds, judged by colour and brilliancy only.

Really good stones	...	12 per cent.
Marketable stones	...	45 „
May be cut ...	...	20 „
Useless as gems ...	...	23 „

Many of the Bingara and Inverell diamonds would undoubtedly be classed first water by the expert. These are white, clear, and bright, and free from speck or flaw. One of the small stones exhibited is of a decidedly green tinge, and another is a light red or pink shade. We have repeated opinions from the best cutters, that our Bingara diamonds are "hard," so hard that up to the date of writing, lapidaries are unwilling to cut them for current prices. That they can be cut is certain, but the hardness combined with the small average size makes the merchant rather unwilling to purchase.

In the *Australian Mining Standard* of July 29, 1893, the following letter appeared from Mr. Edwin Streeter, F.R.G.S., of London, who says:—"I have read with much interest a letter of your correspondent with reference to Bingara (N.S.W.) It is a corroboration of my oft-repeated assertion that the wealth of Australia will prove in time to be equal, if not superior, to that of South Africa. I notice, however, that your correspondent is

in error in saying that the difficulty in cutting Bingara diamonds has been overcome. It is true, so far, that an attempt has been made, and a machine invented for that purpose, which has, however, yet to be proved efficient. There is every hope that time and science together will be effectual; but it would not be right on my part to allow a statement to go uncontradicted which avers that I and other leading firms have overcome the difficulty; and I trust you will put this explanation before your readers."

To this explanation, the *Standard* adds "that every diamond merchant in England and abroad has refused to cut Bingara diamonds; and Mr. Streeter, we believe, stands alone in having expended money on the experiment."

Mr. Streeter's letter very probably refers to the cutting of diamonds to compete with trade in much softer stones, as Bingara diamonds are being continually cut both in London and Amsterdam. A word may not be out of place here in regard to the commercial side of the industry. As already stated, it is a question of finding larger stones, and geologists have every reason to believe that larger stones will be found. The hardness of the Australian gem may be a quality to enhance its value. Mr. Lewis Atkinson wrote in 1886,[1] that "the market price of Australian Diamonds in the rough state is liable, like that of all other diamonds to great fluctuations, and on the whole they are generally lower than the African diamond, for this important reason, that they are a great deal harder to cut and polish; as, if it were possible to pick out an Australian and an African diamond exactly the same size, weight, shape, and appearance, and to give them to one man to polish, the African stone would be finished in six days, while the Australian stone would take eight days, with this vastly important difference that the Australian diamond would be of greater brilliancy and refracting power than the African stone."

In connection with the admitted particular hardness of the Bingara diamonds, it is of some interest to note that every parcel

[1] Annual Report of the Department of Mines, N. S. Wales, 1886, p. 46.

of diamonds tested gave a higher specific gravity for our diamonds than the recorded specific gravities of South African or Brazilian diamonds. I picked about two grams of the best Bingara stones, and taking the average of two experiments I found Bingara diamonds, specific gravity at 60° F. 3·578. The highest specific gravity recorded by Dana for the diamond is 3·525.[1]

*Messrs. Etheridge and Davies in their report on New South Wales diamonds[2] quote the specific gravity of diamonds from many parts of the world, giving Mr. Harry Emmanuel's work and that of M. M. Jacob and Chatrain as their authority. I reproduce their table, adding for comparison, the specific gravity of some stones collected by myself.

Country.	White Stones.	Yellow Stones.
India	3·524	3·556
Brazil	3·442	3·520
Cape	3·520	
Borneo	3·492	

Bingara, parcel of 19 grams in the author's collection 3·565.

There is therefore some foundation for the generally received opinion that the refractive and dispersive power of Bingara diamonds is high.

*For the last few years I have been using Bingara diamonds in my laboratory for charging the thin discs used in slitting rocks for microscopical study. In crushing the stones, the comparative absence of cleavage, and the dark colour of the powdered diamond are characters that attract attention. It has often been noted that the streak of the diamond is of a grey colour, while that of

*1 I have recently sent a small parcel of diamonds, weighing about 6 grams to Mr. F. B. Guthrie, F.C.S., Acting Professor of Chemistry at the Sydney University, with the request that he would determine the specific gravity of the parcel. He finds the specific gravity of these diamonds to be (mean of two determinations) 3·565. These stones are from Bingara. Mr. Guthrie's determination taken in connection with the figures above leaves no doubt as to the higher density of the Bingara gems.

*2 Annual Report of the Department of Mines N. S. Wales, 1886, p. 42.

even a dark ruby, is white. The Bingara diamonds, including the yellow stones are when, reduced to powder of a grey-black colour. When a Bingara and a Cape stone are separately crushed to an equal grain, it will be seen that the Bingara diamond will not show so many cleavages, in other words the Cape diamond is more sparkling in appearance when powdered. Turning to Messrs. Etheridge and Davies'[1] Report we find that it is therein stated that "the absence of cleavage" is a point much in favour of the New South Wales diamond.

*Quite recently Mr. Leopold Claremount, who is a cutter of gem-stones, wrote to the *Sydney Morning Herald* on the subject of Australian diamonds. He confirms the generally accepted opinion that Bingara[2] diamonds are harder than the diamonds commonly placed on the market. He says, "I have had a great many Australian diamonds pass through my hands, and have found in all cases that they are considerably harder than any other diamonds. It is well known that Indian and Brazilian diamonds are harder than those found at the Cape, and it is not surprising, therefore, that the Australian stones should be harder than the former. It may be mentioned as a curious coincidence in this respect that the Australian sapphires are harder than others. I do not say that the Australian diamonds are too hard to cut. I have cut many, and when cut they have been in every way comparable to diamonds from other localities of the same size and quality, but their extreme hardness renders the process exceedingly troublesome and expensive. Also the veins and ridges which are sometimes produced during the process of polishing diamonds are in these stones of much more frequent occurrence and are extremely difficult to avoid. The specimens so far have been of small size and indifferent quality, but I have no doubt that if the mines are found to yield larger and finer stones I shall be able to cut them successfully at a price which will pay."[3]

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*1 Annual Report Department of Mines N. S. Wales, 1886 p. 45.

*2 He writes of "Australian" diamonds, but as Bingara gems are the only diamonds now sent to London from Australia, he evidently speaks of these stones.

*3 *Sydney Morning Herald*, December 5, 1896.

*The consensus of so many practical men, taken with the high specific gravity I find so notable in Bingara diamonds, should I think allow us to conclude that, the Bingara diamond is really harder, than the diamonds usually found at the Cape or in Brazil.

I have learned the following facts about Bingara diamonds, and as I found the information much needed, I may be permitted to introduce it here. A first-class stone from Bingara when cut weighed slightly under one carat. It sold readily in London for £14 10s. 5d. A Bingara stone with a tinge of green weighed when cut $\frac{1}{2}$ and $\frac{1}{64}$ carat, and sold readily for £10. Four parcels of Bingara stones were sold by one gentlemen, who informs me that the average was four to a carat. It was always difficult to dispose of them, and the figure realised ranged from 4/6 to 8/- per carat on the average. The following extract[1] may be of importance to many. In valuing the diamond one must attend "firstly, to the size of the stone and proportionate shape for cutting; secondly, as to whether they be white and free from defect. Rough diamonds are calculated half their weight, as they are supposed to lose 50% in cutting and polishing. The price of doing this may be estimated at from 12/- to 15/- per carat."

Auburn Vale.—The diamonds found here under precisely the same conditions as at Bingara. The country rock is granite, but the diamond-bearing drifts and their relations to the basalt and the associated minerals are the same.

Mittagong.—Southey's Diamond Mine is situated seven miles south-east from Mittagong. The gems are found here in a drift associated with other gem-stones. The drift is not unlike the Auburn Vale deposits, but the absence of tourmaline is at once apparent. The volcanic-breccia that seems to underlie the drift here, and to which attention has been called by Messrs. Wilkinson and Wood, is thought by many to be the matrix of the diamond. This has to be confirmed. The drift is surrounded by Hawkes-

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[1] Diamond Mining in South Africa by William Hanbly Esq.—Transactions of the Mining Association of Cornwall, Vol. III., pt. i., pp. 17, 18.

bury Sandstone or sandstones of the Upper Coal Measures. Some of the stones found here are of a deeper yellow than the straw colour that makes diamonds "off," so much so that in my opinion they have a beauty of their own as yellow diamonds.

I am not aware of any record having been made of a locality where some good diamonds have been found forty miles south-east of Mudgee. It is close to Sandy Flat and about ten miles east of Cherry Tree Hill. Some alluvial gold mining was being done here in 1885, in ground from twenty to fifty feet. A number of diamonds were found in the sluice-boxes. One was sold for £75, and should have cut into a brilliant of the first water of four carats.

A few diamonds have been found near Dubbo in a redistributed Tertiary drift. But after Bingara and Cudgegong comes Mittagong, where although no great number of diamonds have been found, it was hoped we should find the diamond in its true matrix.

Source of the Diamond.—It can be safely asserted that up to the present no diamond has been found in its true matrix in New South Wales. In every case there is evidence to show that the stones were drifted from their original matrix to the place where we find them. The nature of that matrix is also unknown.

The occurrence of the diamonds found now and again at places as far apart as Trunkey, Muckerawa, Tia, near Walcha (a fine stone was found here last month), Uralla, Narrabri, Dubbo, throw no light on the possible source of the diamond in New South Wales. Contrary to the generally received opinion, I believe that the diamonds of Auburn Vale, Inverell, and Bingara have been derived from a common source. The geological conditions on these fields are the same, the associated minerals are the same, and after all the Bingara field is situated further down on the same river-system. I can hardly say that the Inverell stones are larger, but the tourmaline and other associated minerals are certainly larger at Inverell than at Bingara. The Bingara tourmalines are all small and perfectly waterworn. I do not know that an expert could separate parcels of diamonds from the two

places. But show him the associated minerals, and their more travelled and abraded appearance at once singles out the Bingara stones.

*Mr. Norman Taylor propounded the theory that our diamonds were chemically formed in the drifts just where we now find them. Messrs. Etheridge and Davies at the date of writing their report, accepted the explanation offered by Mr. Taylor. They say:—"With regard to the source of the diamond in New South Wales we do not see any other course than to unhesitatingly accept the explanations offered by Mr. Norman Taylor, so far as the facts bearing on this branch of the subject have been yet gathered. He believes that they were chemically formed in the older Tertiary drifts, and in support of this view adduces the following cogent reasons:—

1. The older rocks of the various diamantiferous districts have not been proved to be diamond bearing.
2. The older Tertiary drifts or cements are derived from the denudation of these, and contain diamonds.
3. The younger drifts are only diamantiferous when resulting from the destruction of the latter, and similarly the recent alluvium again from them.
4. The natural conclusion is that the diamonds have been formed in the drifts, and not derived from any pre-existing rocks."

*I would point out that the conclusion come to by Mr. Taylor does not rest on a satisfactory basis. It is quite true as he puts it that "the older rocks have *not* been proved to be diamond bearing." But this is very different from saying, that the older rocks have been proved *not to be* diamond bearing. The italics are mine. Until we can say that the older rocks are not, or were not diamond bearing Mr. Taylor's conclusion is premature.

*I examined the drifts with great care, both in the Inverell and Bingara districts, and could not find any evidence of these drifts having been subjected to any exceptional influences such as we

should expect if the diamond had been formed *in situ*. I admit, however, that while it is easy to find seeming flaws in Mr. Taylor's views, it is not so easy to advance another theory, and duly support it with observed facts. The most I am prepared to do is to state that :—

1. There is no direct evidence that the diamond was formed in the drifts *in situ*.
2. The character of the drifts lend no support to the theory of the formation of the diamond in these drifts.
3. The gems that are found with the diamond have been derived from various matrices, by the denudation and degradation of the older rocks. As the diamond occurs under similar conditions, it is probable that it was also derived from a matrix that exists, or existed higher up the Dividing Range.
4. The Bingara diamonds show very little signs of abrasion, but their small size and hardness should explain this, even though they had travelled from a distant source.

*The late Mr. C. S. Wilkinson, was of opinion that the "source of the diamond may be in the metamorphosed Carboniferous or Devonian beds, where they have been intruded by porphyry."[1] Mr. Stonier after examining the Bingara district, abandons the theory that the diamonds were formed in the drifts. He suggests (1) serpentine or (2) tourmaline granite as a possible source. My own investigations lead me to the conclusion as already stated, the Bingara and Inverell diamonds are derived from a common source—in my opinion some eruptive rock occurring higher up the Dividing Range than any diamond bearing wash yet discovered.

*If the Bingara diamonds are derived from serpentine, a different source must be sought for the Inverell gems, as there is no serpentine whence they could be derived within the watershed of Auburn Vale or Staggy Creek. As for the granite, while admitting it as a possible matrix, I must say I never saw anything pointing to that rock being the source whence the diamonds were derived.

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[1] Annual Report Department of Mines N. S. Wales, 1878, p. 137.

I am of opinion then that the Bingara and Inverell diamonds were derived from a common source, and that naturally this source is nearer to the Dividing Range than any deposits hitherto discovered. As far as I could see about Bingara the deep lead of the ancient river has not yet been touched. No deposit worked looked at all like a main gutter. The late Mr. C. Lowe, of Sydney, made a laudable effort to sink on the "deep ground," and had already pierced the upper basalt and got one hundred feet into the lower rock, when the work was abandoned. This is a matter for extreme regret on public grounds, and everyone interested in Australian diamonds looks forward to the completion of this promising work.

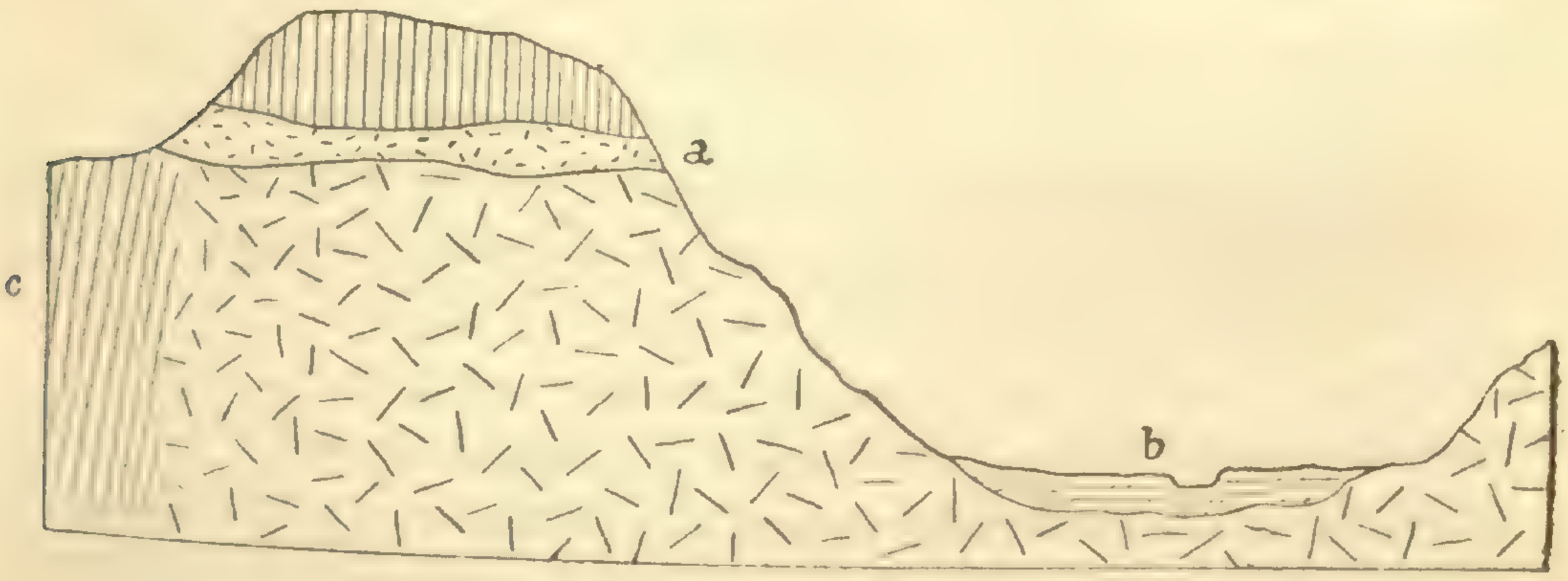
Until enterprise shall cut the deeper beds of the mighty river that rolled west from the mountains of New England, no one may say that our country cannot yet glory in her gems, as she has gloried in the mines of gold and silver that constitute her rich inheritance.

Sapphire.

Sapphire of every known shade from white to the royal deep blue have been found in this Colony. But the percentage of first-class gem-stones to the total quantity recovered is extremely small. The writer has seen more than one parcel of sapphires from New England weighing 20 lbs., from which not more than two or three first-class gem-stones of 1 to $1\frac{1}{2}$ carats were obtained. Very many sapphires have also passed through my hands from Tumberumba, but I have only noted one example of a perfect stone. Professor Liversidge, in his work on the "Minerals of New South Wales" already referred to, says (p. 196) that sapphire is widely distributed over the New England district, but that the New South Wales sapphires in common with those from other parts of Australia are usually rather dark in colour. They are, however, found varying from perfectly colourless and transparent, through various shades of blue and green, to a dark and almost opaque blue. One or two green-coloured sapphires, oriental emeralds, are almost always met with in every parcel of a hundred or so specimens, also blue and white parti-coloured stones.

This agrees exactly with the writer's experience, but having actually collected sapphire from various districts, I describe the deposits in which the sapphire is found in the following localities:

Tumberumba.—At Tumberumba where sapphire is not uncommon, the gem is obtained chiefly when working Pleistocene and recent deposits for gold. These deposits are derived to a great extent from the denudation of a Tertiary lead, portions of which still remain capped with basalt high above the level of the present streams. The relations of the deep lead to the Pleistocene are shown on the accompanying sketch. Both deposits have been



Section at Tumberumba showing *a*, alluvial drift with gold and gemstones covered by basalt; *b*, Pleistocene deposits with gold and gems made up in part of the redistributed drifts from *a*; *c*, Slate.

fairly well exploited in the pursuit of gold. The geology of the district has been dealt with by Mr. Wm. Anderson.[1]

During a short stay in the district a few years ago I had an opportunity of examining the Tertiary lead, as active mining operations were being carried on at the time. Very little sapphire was found in the deep lead (*a* in diagram), the bulk of the corundum coming from the Pleistocene and recent deposits (*b*). Associated with sapphire I noted spinelle, topaz, andalusite, and garnet. The Pleistocene deposits containing the gems were

[1] Notes on the Tertiary Deep Lead at Tumberumba, by Wm. Anderson —Records of Geological Survey of N. S. Wales, Vol. II., p. 21. See also J. E. Carne, in the Annual Report of the Department of Mines N. S. Wales, 1894, p. 120.

derived from the degradation of granitic, basaltic, and slate rocks,[1] as could be seen from the boulders of these rocks contained in "the wash." A number of tunnels have been driven at various points along the valley to catch the "deep ground" under the basalt (at *a*). Although I noted topaz and spinelle from these drifts, sapphire was not present, or at least exceedingly rare. The spinelles from the Pleistocene drifts are the finest I have seen both for size and colour. Some excellent stones were recovered by a floating suction dredge that lifted the auriferous gravels from some of the deeper water holes on the creek. A specimen in my own collection is an almost perfect octahedron. The topaz were invariably small, while the andalusite was sometimes found in long pencil-like specimens showing a pearly lustre. An analysis of this mineral is given by Mr. Card, *loc. cit.*, but it is stated that no definite crystalline form was observed. In my own specimens, however, the rhombic character of the andalusite is at once apparent. Cyanite is not uncommon with the andalusite. It occurs in transparent blade-shaped crystals of a light blue colour, with very perfect cleavage faces. *Mr. Card has also noted cyanite from Tumberumba, and also identified some specimens in my collection.

With regard to the character of Tumberumba sapphire there is nothing exceptional to note. The bulk of the stones are dark, and far too opaque for cutting. A peculiar pitting on the prismatic faces so characteristic of some New England sapphires is not seen on these stones. Crystals partly waterworn have been found up to three-eights of an inch in diameter. All the cut stones I have examined might be called medium in quality. Their greatest shortcomings were in the point of colour, a greenish-blue tint predominating, but in lustre and life these gems were faultless.

Berrima and Mittagong.—Mr. Wilshire, P.M., of Berrima, has collected a considerable variety of sapphire from the drifts of

[1] Andalusite has been already recorded from Tumberumba by Mr. G. W. Card—Records Geological Survey of N. S. Wales, Vol. IV., p. 130.

Wingecarribee River. Some of these sapphires are nearly one inch in diameter, and present more variety in colour and lustre than any other sapphires I have met. Zircon and spinelle are found with the sapphire. With regard to the deposits in which these are found, they are in every instance that I have examined in Pleistocene drifts resting on Hawkesbury sandstone, or sandstones of the Upper Coal Measures. There is an intimate connection between the distribution of the sapphire in this district and the denudation of basaltic areas. This will be touched upon later on. It is worth noting that pleonaste invariably accompanies the sapphire in this district, and that pleonaste occurs as a primary constituent of basalt at Kangaloon.

Kiandra.—Sapphire has not been found plentiful at Kiandra, but as it undoubtedly occurs there, a short description is given of the conditions under which it is found. An extensive Tertiary "deep lead" has been preserved at Kiandra, and over the country to the south, by an extensive capping of basalt. Any sapphires found hitherto have been discovered in Pleistocene drift formed from a redistribution of the material of the deep lead. The section herewith shows the composition of this lead measured close to the town of Kiandra.

New England.—There can be no question that more sapphire is found in New England than in any other part of the Colony. The gem-stone, although distributed over a large area is remarkably similar in its mode of occurrence. The geology of New England has been dealt with by the late Mr. Wilkinson,[1] Professor David,[2] and others. These authors have also in the works referred to, dealt with the occurrence of gems. Broadly speaking, it may be stated that sapphire is found in drifts all over the tin districts of New England, an area embracing several thousand square miles. They were found in great abundance in the surface

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[1] Mines and Mineral Statistics of N. S. Wales, 1875, Government Printer, Sydney.

[2] Geology of the Vegetable Creek Tin-mining Field, by Prof. T. W. E. David, 1887.

tin deposits to the south of Emmaville, and between that town and the Severn River. They can still be obtained in considerable quantity at Sapphire in the drift of Fraser's Creek. Between Inverell and Glen Innes the road crosses a high basaltic range. It may be safely said that sapphire occurs in all the drifts of the creeks that head in the western slopes of this range; the creeks that drain the country round the White Rock, for instance, Swan-brook, King's Creek, Paradise Creek, and the drifts on various parts of Newstead and Elsmore. Further west beyond Inverell, the diamantiferous country is reached, and although sapphires are also found here, they are nowhere so abundant as in the localities referred to. Sapphires are almost continually being found when washing for tin-stone. It must be noted though, that sapphire is more plentiful in the Pleistocene deposits than it is in the Tertiary leads, as is also the case at Tumberumba.

*Some very fine sapphires are found a few miles from Crookwell, on the Goulburn side, but they have never been systematically mined for. All that have been won were got in alluvial ground (in basaltic country) while looking for gold. The very large number of sapphires coming from New England is accounted for by the fact that they are got when mining for tin. There is no tin in the Crookwell drift, and the gold has not been mined for on any large scale, so the value of the gem-deposits remain unknown.

Character of the New South Wales Sapphire.

It is well known at this date that although sapphires are abundant in the Colony, the proportion of good gem-stones is extremely small. I have seen some hundreds of stones ready for export, and Mr. Murfin, lapidary, of Pitt-street, Sydney, has cut a number for my own collection. But a really first-class stone more than a carat in weight I have never met. The Rev. Joseph Campbell when at Glen Innes had some really good stones, but all under half a carat.

Taking the best stones, I may mention a stone that in the rough was half an inch long and of a lovely velvet blue. It was found

in a Pleistocene drift on the Severn River, and was sold to the trade for £10. I examined a parcel of nine pounds in rough of sapphire, collected in and around Emmaville, without finding one faultless gem of half a carat. Most of the stones were dark blue, many almost black, but all showed prismatic or pyramidal faces and bright basal cleavage surfaces. The more transparent stones showed a dark blue-green when viewed across the prism, and a deep blue when seen along the axes. Quite a number were banded in alternate blue and colourless lines parallel to the basal plane.

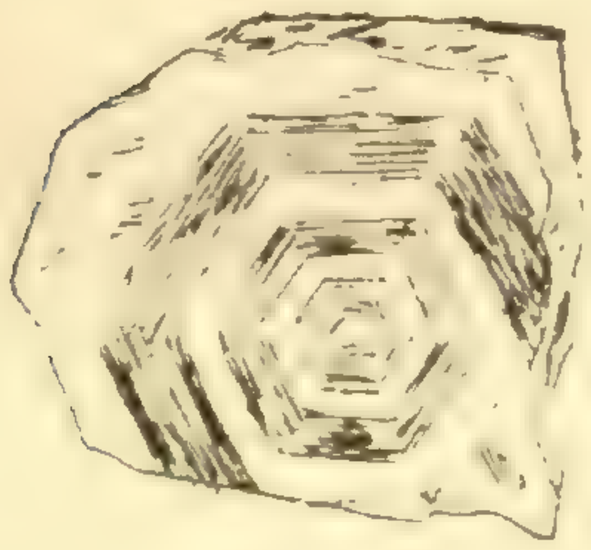
Plate 16, fig. 2, shows the general appearance of the New England sapphires. The peculiar surface pitting shows well on the original photograph, but is rendered somewhat indistinctly in the process block. This character is not seen in the sapphires from the southern districts, nor is it noticeable on any Queensland sapphire that I have seen.

On the extreme right of *Plate* 16, fig. 2, a few crystals can be found showing parallel lines running obliquely across the prisms. In one specimen the alternate lines have a reddish tinge which gives the crystal a remarkable appearance. It is most unusual to find any suggestion of a cleavage in sapphire other than the basal. The lines referred to are certainly structural.

Professor Judd and Mr. Barrington Brown have recently described some structures in a "Contribution to the History of Corundum."[1] The paper deals with rubies of Burma. The authors speak of the corrosion of rubies in deep seated rock masses. The corrosion follows "certain planes of chemical weakness, analogous to the cleavage planes, gliding planes, and other directions of physical weakness. The principal of these solution planes is the basal plane. Other less pronounced planes of chemical weakness exist parallel to the prism faces. Unaltered corundum is like quartz, destitute of true cleavage, and breaks with a perfectly conchoidal fracture. If, however, gliding planes

[1] Proceedings of the Royal Society of London, No. 345, p. 392.

and lamellar twinning be developed in corundum (like those so easily produced in the same way in calcite), parallel to the fundamental rhombohedron of the crystals, then these gliding planes become solution planes." The explanation applies exactly to the New South Wales stones. I had a face ground parallel to the basal plane on a large crystal marked in the manner described, and fine lines could easily be noted crossing the prism to join the parallel and inclined lines seen on the prism.



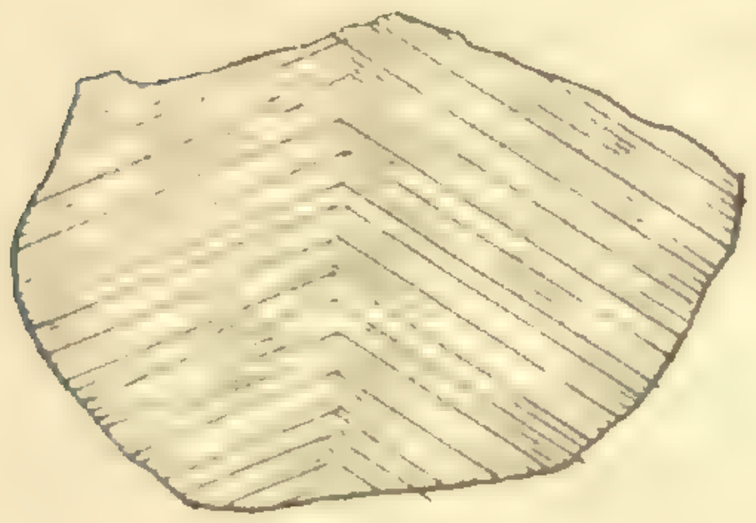
Cleavage fragment of a sapphire from Emmaville district, showing alternating bands of blue and white.

Crystals are rather common that show a clear white line along the axes, and alternate layers of dark blue and light material are repeated from the centre outwards. Many of the stones are a light yellow colour, with the top of the prism just showing a spot of blue. A stone of this description was cut by Murfin, and made a rather handsome gem. When putting a final polish on the table a hexagonal barrell-shaped piece dropped out, leaving a regular faced cavity for the full depth of the stone. I have a stone showing alternate bands of opaque blue and opaque white in successive hexagons from the centre. Small stones banded blue and honey-yellow, and blue and white, are not rare.

As already stated, the sapphires from Tumberumba are all blue or blue-green. The New England stones are opaque blue, Antwerp blue, greenish-blue, greenish, bottle-green, and yellowish-green.

Compared with good gems the New England stones show a want of life, probably owing to being invariably too dark when they show the true rich velvet blue. I tried the experiment of having the dark stones shallow table cut. The effect was a want of life that the improved colour did not compensate for. There is one quality in the New England gems that is unsurpassed, and that is in their surface lustre, being exceeding bright, reminding one of the adamantine flash of sphene.

The colours of the sapphire found about Berrima[1] vary far more than in the stones just referred to. It will be understood though that the stones good enough to place in the hands of the lapidary are as rare as elsewhere. The most notable character of the Berrima stone is the large size the crystals attain. Some opaque but fine bright blue stones measure two-thirds of an inch across, and fragments I saw with Mr. Wilshire, of Berrima, belong to crystals that must have been more than one inch across.



Fragment of a bronze-coloured sapphire from Berrima. The alternating bands are bronze-coloured and honey-yellow (nat. size).

The Wingecarribee drifts have yielded sapphires of a rich honey-yellow, and also of a good bronze colour. These were hardly more than translucent, but when cut *en cabochon*, showed a remarkable chatoyancy and decided asteriated structure. Better examples of asteria structure can be found in New England than elsewhere in this Colony.

Origin of Sapphire.

After some acquaintance with the occurrence of corundum, the writer inclined to the opinion that although topaz and sapphire are often found in the same drifts, yet they are derived from very different sources. I find additional evidence to support that opinion as time goes on. Throughout New South Wales I have noticed that while topaz and other fluorine minerals can be traced into granite country, sapphire is invariably traced to basalt. I am of opinion that basalt is the true matrix of sapphire in New South Wales. In support of this I exhibit herewith a sapphire in a matrix of undecomposed basalt. This specimen was found

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[1] The brown and bronze-coloured sapphires from the Berrima district are notable for their high specific gravity, the average of three determinations giving—

Specific gravity of bronze-coloured sapphire from Berrima at 6° F. 4·419.

Dana gives the specific gravity of sapphire as 3·95 – 4·10.

on the surface two miles north of Swanvale, between Inverell and Glen Innes, and on the western slopes of the range already referred to.

Wherever sapphire is abundant in New England drifts, these drifts can be traced up into basaltic hills, or to areas where basalt has been extensively denuded. It might be argued that this points to the sapphire being derived from the wash underlying the basalt, and not from the basalt. The specimen exhibited is an answer. Moreover when a Tertiary deep lead is preserved alongside a Pleistocene, or recent drift, the latter will often have sapphires, while the deep lead may contain little or no sapphire. The degradation of a basaltic area seems a necessary condition for the presence of sapphire. Tumberumba is a case in point. At Tumberumba we have a deep lead preserved along side, but at a higher level than the present river. I could not get any evidence of sapphire being found in the deep lead. But in the present river valley, which holds detrital materials derived from a basaltic area, the sapphire is found. I have it too on the authority of Mr. Parkins, who has a long experience of the district and is a collector of minerals, that sapphire is found only when the creeks cut through or drain basaltic country.

I have examined many small tin "surfacings" on Cope's Creek. One of these worked at Stanburra yielded nearly every gem stone found in New England, but no sapphire. An examination showed that this tin-bearing country was granite, and that it showed no drifted or transported rocks, that the granite had decomposed *in situ*, setting free the tin-stone and gems. There was no sapphire, but there was also no basalt. In studying the country about Inverell, one is forcibly impressed with the fact that basalt is the source of the sapphire that is found hereabout so abundantly.

To the south of Swanbrook, at Elsmore, Newstead, the principal localities for sapphire are the creeks that head towards basaltic hills such as the White Rock. At Swanbrook and the country to the north extensive sheets of basalt have suffered atmospheric degradation and decay. Paradise Creek, another

notable locality for sapphire, drains an extensively denuded basaltic plateau. The same may be said of a place called Sapphire, further north of Swanbrook.

At Berrima the sapphire is invariably found with pleonaste, so much so that one suspects a common matrix for the two. Now pleonaste can be seen *in situ* in basalt used as road metal about Kangaloon, so there is a strong presumption that the sapphire is also derived from the basalt. This taken in connection with the facts concerning sapphire at Tumberumba and in the Inverell districts, and the specimen of basalt with sapphire *in situ* settle, I venture to think, the question of the matrix of sapphire.

I would add a few lines to describe the basalt containing the sapphire. The specimen is waterworn but fairly fresh, as may be seen where a slice has been sawn off for a micro-slide. Along with the phenocrysts of blue sapphire there can be noted large crystals of a black lustrous shining mineral, which proves to be magnetite. Under the microscope a good deal of ferrite stains the slide, but the rock is on the whole apart from the presence of phenocrysts of magnetite, not widely different from other basalts in the district. The component minerals are augite, olivine, plagioclase, magnetite, and alteration products which sometimes fill cavities and show a black cross in polarised light.

I have never seen anything to lead me to believe that topaz, which is so plentiful in New England, is ever found as a primary constituent of an igneous rock.

The separation of the two gems has also been noted in Burma, and Messrs. Barrington Brown, and Judd[1] write that it is a noteworthy circumstance that none of the silicates combined with fluorine, topaz, etc., are found in the limestones that contain the corundum.

The occurrence of sapphire at Bald Hill, Hill End, is very limited. All the stones found are small.

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[1] Report of Proceedings of Royal Society of London, No. 345, p. 392.

Ruby.

It is a somewhat remarkable fact that while the blue corundum is so abundant, the red variety known as ruby should be one of the rarest of gems in New South Wales. The Bingara rubies are garnet, and the true ruby found in the diamondiferous drifts of that district are invariably small and fragmentary. I have recognised a pale rose-coloured ruby amongst gems from the Tumberumba River. Rubies have undoubtedly been found on the creeks of the Mole Tableland. Here, too, the occurrence is very limited. The only locality where I saw any quantity of rubies with miners was along the Two-Mile Flat, near Mudgee. The best stone from these drifts was in the possession of the late Mr. Milner Stephen. It weighed within a fraction of one carat, was perfect in colour, but showed a "feather on the templet." In the year 1860, the Rev. W. B. Clarke wrote[1] that the occurrence of the ruby with other gems in the gold alluvia of the southern as well as the northern goldfields, is now so common as to need little remark. Professor David must have examined the tin district of New England very minutely, as may be seen in his memoir on the Vegetable Creek Tin-mining Field.[2] The "Geology of the Vegetable Creek Tin-Mining Field," by Professor David, mentions many gems as coming under the author's notice, but the ruby was clearly so rare as not to demand any attention. After an experience of twenty years, the present writer believes that the true ruby is rare,—in fact the rarest of our gems.

Emerald.

Professor Liversidge mentions emerald being found in drifts at Tumberumba, Kiandra, mixed with granite detritus at Paradise Creek near Dundee, and in gneissiformed dykes on the summit of Mount Tennant. Prof. Liversidge states, however, that in some cases it is beryl that is probably meant.[3] From my own experience

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1 "Southern Goldfields," p. 271.

2 Geology of the Vegetable Creek Tin-mining Field, by Prof. T. W. E. David, p. 164.

3 Minerals of New South Wales, by Prof. Liversidge, p. 199.

I must say that I have seen the true emerald in one district in New South Wales only, viz., in the county to the north and north-east of Emmaville. Emeralds have been recognised in that locality in the tin-bearing drifts for some twenty years past; but it was only in the year 1890 that these drifted emeralds were found *in situ*. In that year systematic mining for emeralds was begun, about seven miles to the north-east of the township of Emmaville, by the Emerald Proprietary Company. Attention was first drawn to this locality by Mr. H. M. Porter of Hillgrove. At the present time the Proprietary Company have some shafts down on the property to a depth of one hundred and fifteen feet, at that depth stones of a good colour and quality have been found, but from a variety of circumstances no active work is now being carried on at the mine. It would be a mistake however to conclude that the emerald is confined to this one point of the locality named. I have seen emeralds of a good quality a mile-and-a-half to the north of the Proprietary Company's ground, and I have also seen a good emerald in a granitic matrix, discovered in detritus from a granite cliff, on a creek about two miles nearer to Emmaville.

Occurrence of Emerald.

At the Emerald Proprietary Company's mine the emerald was found on the surface with disintegrated felspathic material, slate-rock, and quartz, not very far from the junction of clay-slate and granite. On opening the ground it was seen that a reef or vein of siliceous materials occurred in slate-rock or clay-stone. The reef travels or trends in a north-eastern direction, dipping at a high angle to the south-east. At various points, proved to a depth of a hundred feet, shoots or pockets occur containing quartz, topaz, tin-stone, arsenical pyrites, fluorspar, and kaolin. These shoots almost always carry emerald or beryl associated with the minerals named. Again some shoots consist for the most part of emerald and beryl only. Glancing over a collection of emeralds from this mine, I noted the following occurrences:—

1. In this specimen an emerald is seen imbedded along its length in pure tin-white arsenical pyrites. In colour this stone is faultless. (A coloured photograph of this beautiful specimen was exhibited.)

2. An emerald crystal, two inches long, completely imbedded in purple fluorspar. Originally the emerald and fluorspar was imbedded in kaolin. When broken across a very perfect hexagonal crystal of emerald was seen to be set in a ring of the purple fluorspar. A coloured plate of this remarkable stone was handed around.

3. Here a long crystal of emerald rests in a quartzose matrix with kaolin and fluorspar.

4. A rock composed almost exclusively of topaz cemented with kaolin ; long acicular crystals of emerald penetrate the kaolin in different directions.

5. White fluorspar enclosing topaz, emerald, and beryl.

6. A red compact felspathic material enclosing abundant crystals of beryl and emerald.

7. This specimen contains purple and white fluorspar, crystals of tin-stone, crystallised quartz, arsenical pyrites, and crystals of biotite.

A number of emeralds and beryls have been found to occur loose in soft kaolin in various parts of the Proprietary Mine. These crystals as a rule are small, (see *Plate* 16, fig. 1) but very perfect in form. The plate referred to gives an idea of their appearance. Some of the crystals are terminated, showing the basal and pyramidal planes. An exhaustive report on this mine by Professor David will be found in the Annual Report of the Department of Mines N. S. Wales for the year 1891.

Size and Value.—The largest emerald found in the Proprietary Mine is estimated to weigh 23 carats ; but this is cracked in several places along the basal cleavage, so that an exceptionally large stone could not be cut from it. A few stones of first quality

have been cut to weigh two carats; but the great bulk of the stones that might be purchased were under one carat when cut. As regards the quality of the stones, the mine has yielded some gems that realised as high as £10 per carat; of course the ordinary run of the stones realise nothing like this figure, being rather light in colour, approaching rather to aquamarine than emerald.

The proprietors of the mine state that 40,000 carats of emerald were yielded in eighteen months. Although the mine is not working at the present time, there is no doubt that a large quantity of emerald is still available. It may be noted here that this is the only occurrence of emerald in Australia in a true fissure-lode, associated with the minerals already enumerated. The Siberian emeralds as is well known, are found in mica-schist. But emeralds are known in pegmatite lodes some five feet wide near Bakersville, Mitchell County, North Carolina.[1]

Although the above mentioned is the only known instance of emerald occurring in a matrix in this Colony, beryl has frequently been noted *in situ*. The greenish coloured beryls mentioned by Professor Liversidge from the Shoalhaven River could not have travelled far from their matrices. Some eight years ago, beryl of good quality was found abundantly in the Elsmore Tin Mines. But the stretch of granite country between Emmaville and Tenterfield, known as the Mole tableland, is the most prolific locality for beryl in this country. The detrital matter from this granite almost invariably contains beryl. As the same detrital material is often washed for the tinstone it contains, beryl is a well known and common mineral amongst the tin mines of that part of New England. Some magnificent crystals have been found, some of the best of which have, to the writer's knowledge, been acquired by foreign museums. Beryl has undoubtedly been found at Ophir near Orange. Good hexagonal crystals of this gem are found in surface sluicing at Cope's Creek on the Auburn Vale side, close

[1] American Journal of Science, Third Series, Vol. XLVIII., Nov. 1894, p. 429.

to the crossing-place to the Round Mount Diamond Mine, and also in the deep alluvial sinking at the Tingha Tin Mines.

Professor David, in the report already referred to, makes mention of a true emerald being discovered at Kiandra.[1]

Probable origin of Emerald.

Professor David writes, *loc. cit.*, "There can be little doubt that the beryls and emeralds have been introduced into the joints or fissures in the claystone by solutions emanating from the underlying intrusive granite." I am of opinion, however, that both claystone and granite received their gems from a common source. The topaz and fluorspar so prominently associated with emerald at Emmaville, are found even more abundantly in the granite than in the claystone. From a similarity in the occurrence and association of fluorspar and topaz in claystone as well as in granite, it seems to me that both granite and claystone were simultaneously invaded by the solutions carrying fluoride of silicon and fluoride of calcium, from which topaz and fluorspar crystallised. A comparison of some of the best emeralds from Emmaville was made with some first-class emeralds from North America and Siberia.

(a) *Colour.*—The Australian stones were in no cases of as deep or rich a colour as the Siberian stones.

(b) *Lustre.*—It seemed to me that the Australian stone was much superior to any others in lustre and life. This may be due in part to the cutting, the gems in my possession being cut by Mr. Murfin, lapidary, of Pitt-street, Sydney.

(c) *Hardness.*—Our emeralds scratch quartz with the same facility as does the Siberian emerald, but both I found somewhat inferior in hardness to the white topaz associated with the emerald, and already referred to.

(d) *Specific Gravity.*—The parcel of crystals photographed on *Plate* 15, fig. 1, have a specific gravity of 2·73. Some samples determined by Mr. Mingaye[2] gave a specific gravity

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1 Annual Report of the Department of Mines N. S. Wales, 1891, p. 231.

2 Annual Report of the Department of Mines N. S. Wales, 1891, p. 233.

of 2·67, while a beryl from Ophir, tested by Professor Liversidge had a specific gravity of 2·708.[1]

(e) *Chemical Composition.*—The following is the composition of an emerald from Emmaville as determined in my laboratory about two years ago by Mr. James Petrie. The analysis of a crystal from Paavo is also given for comparison. This latter is taken from Dana's 'Descriptive Mineralogy,' sixth edition, p. 407.

	Emmaville, N. S. Wales.	Paavo.
H_2O (on ignition) ...	0·62	
SiO_2	65·20 ...	66·37
Al_2O_3	17·80 ...	19·26
BeO...	14·40 ...	14·01
CaO...	1·00 ...	
MgO	0·64	
Na_2O	0·34	
	100·00	99·64

Specific gravity 2·73.

Beryls.

Beryls, as a matter of course, occur with the emerald. The more correct statement of the relation between emerald and beryl is that around Emmaville beryl[2] is common, and that in a few localities there is a small proportion of the emerald. *Plate* 15 shows a number of beryls of the natural size, all from New England. The longest gem on the plate was found by a Mr. Stanley at Stanburra, when ground-sluicing a patch of decomposed

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[1] Minerals of New South Wales by Prof. Liversidge, p. 199.

[2] I have cut several crystals of beryl into microscopic slices. These sections when parallel to the basal plane show successive hexagons from the centre outward, the lines being formed of liquid or gas cavities. The cavities are drawn out parallel to the faces of the prism. When slices parallel to the vertical axis are examined the cavities are also seen to be drawn out in the direction of the vertical axis, so it is evident that the successive shells as they were formed compressed the layers below them in all directions around the vertical axis.

tin-bearing granite. The exact place is not far to the left of the road from Inverell, through Auburn Vale, to the Round Mount Diamond Mine.

In colour the beryls vary a good deal ; some have a very choice light blue, but green and blue-green tints prevail. The peculiar etched specimen on the plate was found in alluvial drift at Scrubby Gully, Inverell. A small prism in my own collection was found in a wash under basalt, on Kangaroobie Station near Ophir. Being of a light green colour, it is probable that some stones of this class are recorded in the "Minerals of New South Wales," as emerald. In fact Professor Liversidge gives it as his opinion that beryl is probably meant.[1] I have had a blue beryl from Tingha cut, and it made a gem that should satisfy the most fastidious. When mounted its brilliancy was faultless, suggestive somewhat of a blue topaz, but with a very much finer surface lustre. *Plate* 15 gives a good idea of the appearance of these stones when found in cradling, sluicing, or puddling for tinstone.

Topaz.

New South Wales excels in this gem-stone. If we except the famous Maxwell-Stuart topaz,[2] the largest and clearest stones in the world have been found in the New England districts of this Colony.

Mode of Occurrence.

The topaz has been found in its original matrix as well as generally in the tin-bearing drifts about Tingha, Inverell, and Emmaville. The association of tin-stone and topaz is very marked and is easy to explain. The tin stone is invariably found in lodes and veins in granite. The same granite has proved the matrix of topaz. Specimens are not rare showing tin-stone, topaz, fluorspar, and smoky quartz, in the same matrix. At the Pro-

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[1] The Minerals of New South Wales, by Prof. Liversidge, London, 1888, p. 199.

[2] Mineralogical Magazine, Vol. III., p. 93.

prietary Mine, Emmaville, beautifully lustrous crystals are found associated with topaz, fluorspar, biotite, and quartz and enclosing crystals of arsenical pyrites. At the same mine a massive rock composed of topaz crystals held together by a white kaolin is common. Professor David records the occurrence of this rock in his report on the emerald mine.[1] At the time of Professor David's visit this topaz rock formed a vein eight inches thick. Since then very much wider masses of almost pure topaz rock have been broken down at this mine. The surface lustre of some of these crystals is extremely brilliant, and without exception they are clear and colourless but flawed across the prism.

Forms.—Crystals of a more robust habit are found at Oban. The Emmaville topaz from the matrix frequently shows the basal pinacoid pyramid and prisms well developed. The Oban crystals have a wedge-shaped appearance that the topaz at the Emerald Proprietary Mine never show. This wedge shape is due to the greater development of the brachydomes. The face *y* of Dana's System of Mineralogy is generally present modifying *f*. The prisms *l* and *n* are usually striated. *M* is occasionally present. In one specimen a cleavage to parallel *f* was very clearly shown. The basal cleavage is as always very well developed.

The largest crystal I have seen is the example figured on *Plate* 13, fig. 3. This weighed a little over sixteen ounces when found. It was discovered in a granitic detritus at Oban in New England. The topaz reproduced on *Plate* 13, figs. 1 and 2, are also from the Oban district. The waterworn example is a perfectly clear white stone weighing a little over seven ounces, and from which a gem could be cut to rival the famous Maxwell-Stuart stone. Fig. 2 on the same plate is an imperfect crystal from Oban with a slightly greenish cast. *The rounded stone shown in fig. 1 being perfectly clear I determined its specific gravity.

Specific gravity of a New England topaz weighing 203·548 grams at 60° F.... ... ... 3·573.

[1] Annual Report of the Department of Mines, N. S. Wales, 1891, p. 230.

*This is a little higher than the specific gravity of the average topaz. The mean of eleven determinations recorded by Dana being 3·524.

Plate 15, fig. 1, shows waterworn pebbles of topaz found with alluvial tin on Cope's Creek.

Plate 15, fig. 2, shows a collection made from Scrubby Gully and the Mole Tableland. No two stones are the same colour in this collection. I have stones cut from all the localities named, and they all exhibit the peculiar glaze-like lustre of topaz. This quality gives to cut stones a distinctive slippery feel that enables one to recognise these stones even in the dark.

Colour.—As to the hue-suite, there is plenty to select from in New South Wales topaz. Writing of Victorian topaz Dr. Bleasdale[1] says that "there is not in the world a stone fit for brooches of size and fire and lustre, and suited to both day and candle-light, equal to some of the blue topazes of Victoria." The same can with truth be said of the topaz of New England. When well cut and polished with care (there is as lapidaries say a 'grain' in topaz) they have all the qualities that a gem should possess,—rarity, durability, hardness, and beauty.

A light lemon-yellow topaz is often seen in collections. I do not think a true yellow topaz has yet been recorded. The specimen numbered 297 on the plate is typical of many stones found in the way of colour. The centre of the stone is a delicate warm amber-brown, while both ends are tinted with a bluish-green. The stone alongside, 299, is a faultless blue with a brilliancy that asserts itself even in the rough stone. Sea-green and pink varieties are in the possession of every collector. Good topaz were at one time coming from Tingha, where they were found both in the shallow working for tin known as sluicing-ground, and in the deep ground covered by basalt. Some good stones are still found about Emmaville and Oban.

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[1] Intercolonial Exhibition Essays 1866-67, No. 4—Gems and Precious Stones found in Victoria, by the Rev. John J. Bleasdale, p. 8; and p. 244 of complete volume.

Herewith is an analysis of a topaz from Emmaville, to which are added for the sake of comparison the figures for a Tasmanian topaz, extracted from Dana's "System of Mineralogy."[1]

	Emmaville, N.S.W.	Tasmania.
SiO_2	30·29 ...	33·24
Al_2O_3	60·90 ...	57·02
CaO...	0·40 ...	0·83
F	15·05 ...	17·64
	106·64	
	6·34 less O = F_2	
	100·30	

Specific gravity 3·50. Colour bluish-white.

Garnet.

It would be hard to find a district in the Colony where garnet in one variety or another may not be found. Massive garnet rock is not uncommon. A garnetiferous lode was found gold-bearing and worked with profit near Molong. Massive garnet is found near Minore Railway Station. Masses of magnetic iron and garnet are found near Binalong. Garnet rock must occur in abundance in the Tumut district. Numbers of samples are collected by miners and prospectors. Professor David first recorded the exact localities for garnet in the Emmaville (Vegetable Creek) district, as for example, at Boiling-Down Creek and Patterson's Reef.[2] Garnet fit to be classed as a precious stone is not common. Certainly no garnets have been found here to compare with the stones from the MacDonnell Ranges, or with those occasionally sent down from Queensland. The best garnet I have seen *in situ* occurs near the Tamworth-Bingera road, twelve miles from the last-named town. This locality was examined by the writer in 1892. A note by Mr. D. A. Porter[3] referring to the same place, speaks of the garnets as lying on the

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[1] Dana's System of Mineralogy, 1892 edition, p. 494.

[2] Geology of Vegetable Creek, by Prof. T. W. E. David, p. 165.

[3] Journ. Roy. Soc. N.S. Wales, Vol. xxviii., 1894, p. 40.

surface, and he notes that they had the appearance of not having travelled far. I found several pieces of a coarsely crystallising basic rock containing the garnets *in situ*.

The garnet is found close to an isolated hummock of basalt that cannot easily be connected with the other basalts of the district. The probability is that the basic rock referred to is a segregation from the basalt, or a selvage in contact with the country rock, should the basalt be found to be an intrusive mass. The rock must have been denuded considerably, as garnet can be washed from the soil around for a considerable distance. At the time of my visit, the stones were considered to be rubies, and the ground was taken up to mine for the gems. The mistake was a pardonable one, with men who are accustomed to consider every stone with a fine red colour a ruby. I collected some of the stones, and in violation of all the traditions of the lapidary insisted on having the stones cut as brilliants and not *en cabochon* or carbuncle style. The result was decidedly pleasing. The cut stone shows a perfect "pigeon-blood" red by reflected light, but a rather muddy hyacinth red by transmitted light. The fracture, single refraction, fusibility, and hardness, show that they have all the life and beauty of true gems.

The matrix of this garnet already referred to is an interesting rock. It might be described as a holocrystalline granular, basic rock, composed of pyroxene, felspar and kelyphyte rings of a composite substance surrounding garnet. The garnet in question is nearer to pyrope than almandine, and it is remarkable that Diller[1] describes an American rock with pyrope surrounded in a like manner by radial shells of biotite and magnetite. A very similar occurrence is figured by Rosenbush.[2] An analysis of this interesting rock is here given :—

Basic rock from Bingara	H_2O (on ignition) ...	1·2
	SiO_2	42·4
	Al_2O_3	18·4

[1] Bull. No. 38, United States Geological Survey, p. 15.

[2] Micros. Physiographie Petro. Wichtigen. Minèrallen, Taf. XIV.

Basic rock from Bingara	Fe_2O_3	... ...	10·4
	MnO ...	... ...	trace
	CaO ...	... ...	16·6
	MgO ...	... ...	8·5
	K_2O } Na_2O }	... ...	2·5
			100·0

Specific gravity 3·1.

I have stated that the garnet itself is pyrope. A few grains of the best coloured stones were picked from a quantity of the washed sand. The following is the analysis. An analysis of a South African garnet is also given from Dana's "System of Mineralogy."

	Bingara.		South Africa.
SiO_2	39·57	...	40·90
Al_2O_3	23·68	...	22·81
Fe_2O_3	0·18	...	1·48
FeO	10·04	...	13·34
MnO	3·76	...	·38
CaO	8·76	...	4·70
MgO	14·45	...	16·43
	100·44		100·04

Specific gravity 3·743.

Mr. G. W. Card has described a garnet-bearing sand from Bingara.[1] This is probably the same garnet. The presence of the pyroxene and magnetite strengthens this opinion. But Mr. Card describes his specimens as almandine. I am aware however, that garnet is found in several other places around Bingara, but I have no personal knowledge of these stones.

Garnets of good colour, quite fit for gems, are found in the auriferous sands of Cuninghame Creek, near Murrumburrah. Interesting dyke rocks intersect the granites of this locality. An intrusive dyke of leucite basalt was discovered about two miles south of Murrumburrah by the writer, and a mile or so further

[1] Records of the Geological Survey of New South Wales, 1893, Vol. III., p. 111.

south, at Nimby, another basalt dyke is seen to be the matrix of the red garnets. This dyke can be traced from a point just in front of Mr. Edward Fallon's house in a southerly direction for a mile or more. In that distance the character of the stone changes somewhat. At the south end the basalt stands out in little hillocks, and is not in any way remarkable in hand specimens. Further north phenocrysts of a dark lustrous mineral show in the stone. These are sometimes one inch in diameter, giving the rock quite a distinctive appearance. Through the courtesy of Mr. John Burke, J.P., of Murrumburrah, I was able to sink a few feet through the rock. Some interesting specimens were thus secured. I had the satisfaction of finding the blood-red garnet *in situ*. In most cases the garnet was associated with common olivine, which occured in the basalt in nests measuring half an inch across. The olivine was granular, and of various shades in the same mass, sometimes of a rich sapphire green of so fine a colour as to rise to the dignity of chrysolite. As regards colour this chrysolite is perfect, but unfortunately no specimens of any size were found. It was not easy to procure specimens pure enough for analysis, indeed the results of the analyses made vary so much that I am not prepared to give them here. The stones show no cleavage, are dark between crossed nicols, and are fusible before the blowpipe. Specific gravity 3·78.

The large lustrous black phenocrysts in this basalt were corroded and rounded, and had evidently floated some time in the molten magma. These were found to be pyroxenes, closely allied to augite.

The following is an analysis of the pyroxene with an example of a St. Vincent augite for comparison. This last is taken from Dana's "System of Mineralogy," p. 361, edition 1892.

	Pyroxene from near Harden.			Augite, St. Vincent.
SiO_2	49·80	...	...	45·14
Al_2O_3	9·90	...	...	8·15
Fe_2O_3	8·64	...	...	5·25
CaO	15·80	...	...	19·57
MgO	15·86	...	...	14·76
	100·00			

Garnets of good colour are not uncommon in the Broken Hill district. Broken Hill silver ores often show abundance of bright red garnets. Mr. Geological Surveyor Jaquet[1] is of opinion that these garnets were derived from the walls of the lodes rather than formed *in situ* from mineral-bearing waters.

Garnets of good colour are also found plentifully in the sands of some creeks at Poolamacca. Mr. Brougham of Poolamacca Station, has had some very fine stones cut. The blacks hereabouts are adepts at washing the sands for garnets, and I may add adepts too in gauging the value of a stone.[2]

Zircon.

In dealing with sapphire I had occasion to mention the presence of zircon, both at Tumberumba and Berrima. I have also collected zircon in the sluicing-boxes at Araluen, and amongst the alluvial tin-stone of the Emmaville district. I have had stones cut by Mr. Murfin, from Berrima and Tumberumba. These would be called hyacinths. I have not noticed the peculiar opalescence that zircon sometimes shows, in any of our gems. All the stones I tried before the blowpipe lost their colour on heating. There is an abundance of zircon in the auriferous drifts and alluvial tin deposits, but even good stones have so little commercial value that the miner cannot afford time to save them. This is rather a pity, for after all, the zircon is a lovely gem with a magnificent lustre that should entitle it to be highly prized. The best stones hitherto found come from Hanging Rock, near Nundle, where for some time they were believed, by the miners to be diamonds.

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[1] Geology of the Broken Hill Lode and Barrier Ranges Mineral Field, by J. B. Jaquet, Sydney, Government Printer, 1894.

[2] Almandine garnet (derived from older rocks) has been described from the Hawkesbury Sandstones near Sydney, by Mr. Henry Smith. They are small and not plentiful, indeed they are so rare that I am not aware that any collector has succeeded in getting a single ounce of the garnets together.

Turquoise.

Turquoise is found in one district only in New South Wales, viz., near Bodalla; the exact locality is at a bluff on the left bank of Mumuga Creek, half a mile up the stream off the main road from Bodalla to Wonga Heads. The bluff consists of highly-inclined and in some places contorted Silurian slate. This gem-stone was discovered here early in the year 1894, by Mr. S. Lorigan, of Bodalla, when prospecting for gold. Locally the stone was thought to be one of the ores of copper. The credit of recognising its true nature is due to Mrs. Laidley Mort, of the Bodalla estate. Shortly afterwards some samples were se nt to the writer, who forwarded an analysis of the turquoise to Mr. Lorigan. This showed that the stone was a phosphate of alumina and copper, or in other words a true turquoise. At the date of writing (1896) some men are mining for turquoise with varying success. Some excellent samples of turquoise have been found, but it is fairly settled, that the great bulk of the turquoise found here is not marketable as a gem-stone. When I visited the mine, Joubert and party had close on one hundredweight of turquoise, but most of this was faulty in colour, and not perfect in texture. Much of the stone is found on polishing to be rather porous, certainly not as compact as good turquoise should be. The bulk of the stones, too, have an objectionably green tinge. At the same time I must admit that a few picked stones are quite equal to turquoise of the best quality.

Occurrence of the Gem.

The turquoise generally occurs as :—

(1) Thin crust-like seams filling horizontal joints in the slate.
(2) In rounded marble-like balls in vugs of the slate.
(3) As concretionary masses in similar vugs.
(4) In thin lenticular plates in black slate associated with iron pyrites.

The slate-rock is dark in colour, and at a short distance from the surface is always found charged more or less with iron pyrites. This pyrites when separated from the stone contains gold at the

rate of two pennyweights to the ton. It has been mentioned that the turquoise has been found in concretionary masses. These balls, it may be noted, are oftentimes found completely imbedded in a very dark carbonaceous earth. The joints in which the turquoise occur are, as a rule, at right-angles or nearly at right-angles to the bedding-planes of the slate.

When seen *in situ* a good deal of the turquoise appears of a good sky-blue. When mined and stored for a while the blue colour alters to a bluish-green, and often to a decided apple-green, showing little or no blue. The thickest seam found up to the present measures three-sixteenths of an inch in depth. Some of the best coloured stone is not more than one-sixteenth of an inch in thickness. Slabs of turquoise six inches long by three inches wide have been taken from the mine.

With regard to the origin of the turquoise in this particular locality, there is very little evidence to base an opinion on. Prof. F. W. Clarke is of opinion that the turquoise of the Los Cerrillos mines is of local origin, and he emphasises the idea that it has resulted from the alteration of some other mineral, for instance from apatite. The existence of pyrite in the gold-bearing veins may have had something to do with initiating the process of alter ation, and the alumina of the turquoise was probably derived from decomposing felspar.[1]

The presence of pyrites in the matrix of the New South Wales stone is a circumstance worth noting in this connection. It has been already stated that carbonaceous slate-rock is the matrix of some of the turquoise. In more instances than one I have noted at Bodalla concretionary turquoise, surrounded by a black powdery granular material not unlike a black oxide of manganese. But the borax bead shows no reaction for either iron or manganese. On heating, the carbonaceous nature of the material is at once made clear. If this carbon has had an organic origin a possible genesis for this phosphate-bearing gem is apparent.

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[1] Gems and Precious Stones in United States, Canada and Mexico, by G. F. Kunz, p. 57.

The specific gravity of Bodalla turquoise is 2·67, it has a hardness of 5·5 to 6. The chemical composition of an average sample is :—

**Analysis of Turquoise.*

H_2O on ignition	21·000
SiO_2	0·500
CuO	7·450
Al_2O_3	36·236
Fe_2O_3	1·264
CaO	1·700
P_2O_5	31·900
	100·05

In a closed tube this turquoise gives off water, decrepitates, and on further heating turns black. Alone it colours a Bunsen flame slightly green, and with hydrochloric acid a vivid blue. The pure varieties are almost entirely soluble in hydrochloric acid, making a grass-green solution.

It has been stated that the turquoise described loses its colour with age. This may have arisen from the fact that seams of turquoise are found at the mine altered to a white porcelain-like material. Some polished samples in my own collection, although exposed to a strong light for about two years, have not altered in colour. A sample of a fine bluish-green colour, cut and mounted as a brooch, has not altered in colour since cutting eighteen months ago. I have observed that the turquoise does alter somewhat immediately after being removed from the parent rock. This I attribute to a loss of water, for the gem loses weight as well as colour when placed in the cabinet. Once dried, as far as my experience goes, the colour then assumed is permanent.[1]

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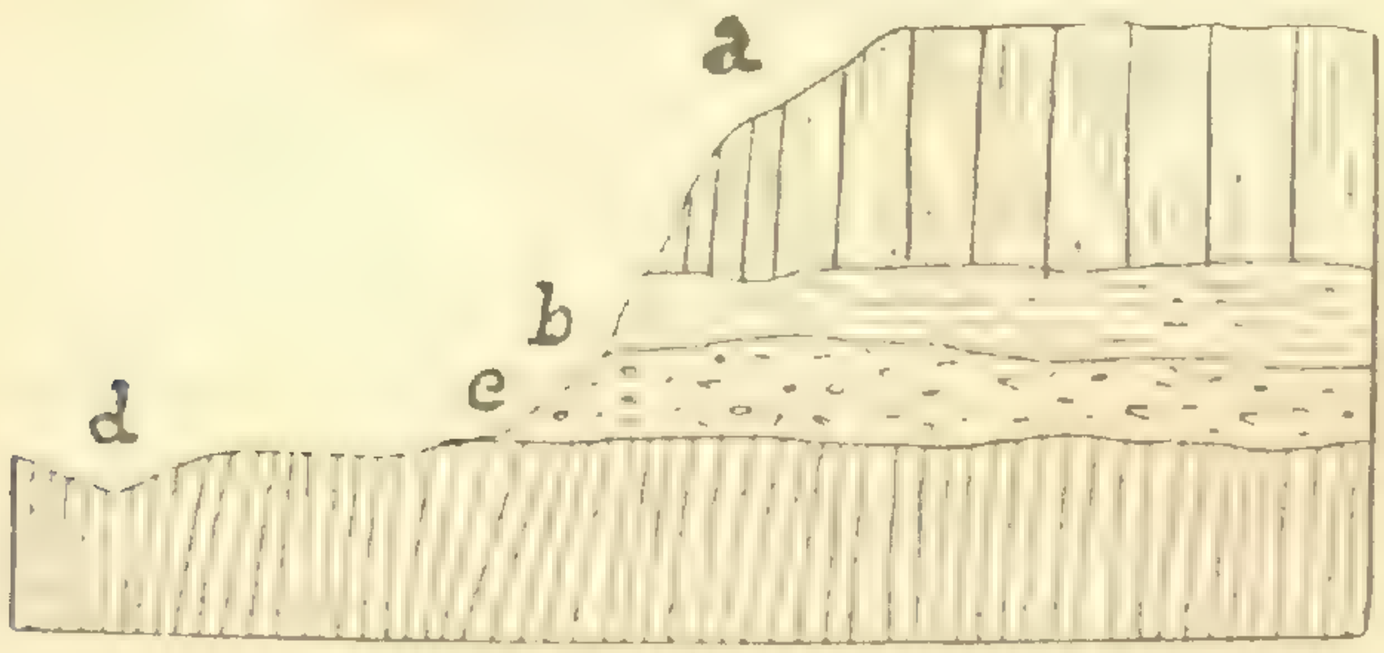
[1] Since my visit to Bodalla turquoise has been found in some other localities of this district. A record of turquoise being found here, has been already made by Mr. Card—Records Geol. Survey of N. S. Wales, Vol. IV., p. 20.

Opal.

The noble or fire opal, or the only variety that may be called a precious stone, is found in two localities only in New South Wales, namely, at the White Cliffs, about fifty miles from Wilcannia Station, and at Rocky Bridge Creek, near Trunkey.

At Rocky Bridge Creek the opal fills vesicular cavities in a decomposed acidic or andesitic lava. The lava rests on auriferous gravels and sands of the usual Tertiary type. Some of the stones found here are of the finest possible quality. The larger stones



Section at Rocky Bridge Creek. *a*, andesitic trachyte with noble opal in vesicular cavities. *b* and *c*, indurated sand and drift. *d*, Silurian slates.

found are rather milky but show fine colours. The small gems lately got by Mr. S. Davis, of Carcoar, are not to be surpassed,—equal to the best Hungarian. As is well known the Wilcannia and Queensland opals are found encrusting or filling cracks, and the finest stones often want depth. The Rocky Bridge opals occur in the matrix in rounded pea-shaped pieces. When a good stone of this kind is found, it can be cut to the best advantage. I do not think that the search for these opals ever has been remunerative. There is a difficulty in getting out the gem,—at least the miner finds it difficult without a cutting wheel. At present some men are at work, and as first-class stones have been found and the vesicular lava is extensively developed, more gems are certain to come to light.

At the White Cliffs the opals occur in quite a different way. They are not in any way connected, so far as I could see, with

igneous rocks. The opal is found in Upper Cretaceous Sandstones, lining joints and filling fissures both vertical and horizontal. Shells and other fossils are found completely opalised. As might be supposed only a part of the opal found is of any value as a gem. The dull, milky, and opaque stones are called "potsh" by the miners. Messrs. Hoffnung are large buyers of the better class of the opal found here. Much of the stone is cut at their Sydney establishment, but the greater quantity is exported to Europe and America. I have at various times received opaline stones from other localities within the cretaceous area, as far north as Mount Brown.[1] Mr. Slee gave it as his opinion some years ago, that opal would be found over a large area of the far west, and there is every reason now to believe his opinion is correct. The drawback to opal-mining is that there are no surface indications to guide one where to begin operations in the search. Some of the best stone at the White Cliffs is come upon almost by accident.

When sent to the market the Wilcannia stone can be always separated from the Queensland opal. The matrix of the Wilcannia opal is so friable that it is easily removed, and the gem is sent down in the rough. *In fact they are picked out of the "face" in the mines directly they are seen. This is done with a short blade knife, and without removing any of the matrix with the gem. I very often noticed a clear space above the opal along the whole length of the layer. The character of the gem as brought to the surface is shown on *Plate* 17, fig. 2.

The Queensland gems on the contrary are in a matrix of siliceous limonite or hæmatite, or a sandstone cemented by those iron compounds. The matrix can be safely removed by the lapidary's slitting disc only. Exceptions are known, but generally there is the difference shown in *Plate* 17, figs. 1 and 2.

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1 Having gone over a great deal of the north-western districts of the Colony since the above was written, I am not now so hopeful as to the large extent of country indicated by Mr. Slee, being found to carry opal.

As to the quality of the stone,[1] I venture to say, after seeing some hundreds of packages of it both cut and in the rough, that New South Wales is at the date of writing, putting on the market a gem that can be taken as the finest opal in the world.

*Quite recently I spent a few days on the White Cliff opal field and found the output of marketable gems equal to £200 per week. The opal-bearing country as already stated is of Upper Cretaceous age. In this locality opal has been found along a strip of country not more than one and a half miles wide and twelve to sixteen miles long.

*Some of the best finds were made by following surface indication where some opal was left by the weathering of the sandstones, but as a rule, miners sink shafts anywhere within the area indicated with the hope of finding a seam of opal. Even within this area, experience has shown the probabilities of finding good stone is confined to certain localities, that show no specially distinctive features.

*When on good ground the opal is not confined to a single level. I saw opal at three separate levels in one shaft. In one of these drives, two horizontal layers of opal could be seen connected by a vertical film-like sheet of the same material. In Block 1, seams of opal were found at depths of fifteen and twenty-seven feet from the surface, and similar conditions can be observed on other parts of the field. The question then arises, as to the probability of opal being found to considerable depths on the field. Present appearances would appear to indicate that the conditions under which the opal is found cease at a depth of from fifty to sixty feet from the surface. The stratified zone in which the opals occur cannot be described as a sandstone. Mr. Jaquet refers to it as a kaolin. In my opinion, the term marl-stone would be more appropriate. There is no doubt about the matrix being felspathic, and much of it contains sufficient carbonate of lime to effervesce

[1] A remarkable black opal is sometimes found and is valued as a curio. It is when polished a perfect black, and when, as it often happens, it is seamed with white opal, a very pleasing effect is obtained.

with cold hydrochloric acid. The specimen now exhibited containing some noble opal, is a typical white and hard marl. In places, as might be supposed, this marl is deprived of the carbonate of lime and then approaches a kaolin, while it is in most cases stained with iron oxides. The opal now mined is won entirely from this marl-stone, which probably does not go down more than some sixty feet. Below this there is eighty feet of a soft and clayey rock, locally called "slum," a bed not at all likely to contain opal. Under the so called "slum" is a bed of sandstone into which a well was put to the depth of twenty-five feet without finding any traces of opaline rock. About nine miles to the north-east of White Cliffs, the horizon on which opal is found is seen to be succeeded by yellow ochre-like clays. White claystones rest on these and the series is capped by a siliceous conglomerate.

Origin of the Opal.

*One of the first facts to be noted on the opal field is the association of the opal with lenticular masses of a rock, known to the miners as "angle stone," and the "guardian angle stone." This rock has all the appearance of a diatomaceous earth. The rock is also known as "biscuit stone," and this expresses well the peculiar and well known feel of indurated diatomaceous earths. I have made a number of slices of this rock, but have not been able so far to recognise diatoms or radiolaria.[1] I may state that the "angel stone" lies in layers above the opal, and in my opinion is a diatomaceous deposit, or certainly one of organic origin, and that it furnished the silica to form the opal.

*In this connection I may say that I have more than once received specimens of diatomite from the Richmond River, which were in part converted into a true opal. Mr. Krause, Lecturer on Mining at the Melbourne University, describes[2] a tripolite deposit from Lilicur (Vic.). The deposit is seventeen and a half feet in thickness, and covers an area of four and a half acres. He

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1 I have detected certain spherical bodies, but having no special knowledge of these organisms, must hesitate to decide whether they may or may not be radiolaria.

2 Royal Society, Victoria, Vol. xxiii., p. 250.

points out how joints and fissures are produced in the contracting mass "along which percolating waters have caused a partial solution of the silica, and its ultimate resolidification into a colloid form. This process is still going on, and the result is an occasional band or reticular patch of opal of a waxy lustre and pale yellow colour."

*Dr. Cooksey[1] has pointed out that when opal replaces calcite, the cleavage of the latter mineral is preserved, and that much of the reflected light in the noble opal is thrown from these cleavages. I noted opal replacing shells, reptilian bones, and belemnites. The finest opal found was probably a stone which replaced the centrum of some vertebræ of a Saurian—allied to *plesiosaurus*. One interesting form of opal is locally known as "pipe" opal. This I found to be a replacement of a belemnite.

*The occurrence of waterworn quartzite boulders in the opal-bearing marls and kaolins is a matter not easily explained. They are undoubtedly derived from Devonian quartzites, and in litho-logical character cannot be distinguished from the sandstones that are seen on the Broken Hill road about nine miles from Wilcannia, or from the vitreous-like sandstone overlain unconformably by cretaceous beds on the Tallywalka Creek to the east of Wilcannia. Many of these boulders are ten to fifteen hundred weight, and in some cases are completely encrusted by a skin of opal, evidently formed *in situ*. I saw an example where a boulder was surrounded by a layer of gypsum, the latter mineral being replaced in places by opal. They are also seamed with veins of opal. Sometimes specimens of this sandstone are seen to be dotted throughout with specks of fire opal, and these when cut into slabs are magnificent objects for the cabinet of collectors, or for ornamental purposes.

*Apart from accounting for the source whence the boulders were derived, it is not easy to see how they came to be transported with such fine sediments as surround them. The current that could carry along such boulders would not be likely to deposit fine clays.

[1] Records, Aust. Museum, Vol. II., p. 111.

At first sight they lead one to think they had been dropped into position after the manner of erratics, but of this there is no collateral evidence.

There are a number of other stones of little interest that come under the heading of precious stones, that I propose to treat of briefly.

Quartz and its Varieties.

Amethyst.—Is the one variety of quartz most prized as a gem. This stone cannot be said to be rare in the colony. I have collected specimens from alongside a quartz leader, in the cliffs between Eden and Twofold Bay, in highly inclined clay slates. I have a group of crystals found in a cavity in the trachyte (syenite) of Bowral. Excellent examples of a fine colour were found at one time in a tunnel in porphyry at Bowling Alley Point. Professor David[1] notes a vein of amethystine quartz, one and a half feet wide, in New England.

The best coloured amethyst I have in my own collection comes from Oberon. Between Oberon and O'Connell's Plains a quantity of amethyst was discovered in 1890, from which some fine gems were cut.

Rose Quartz.—This rare variety is not often met with in this colony. The only specimen in my collection comes from the Mole Tableland, but it was not collected by the writer.

Black and Smoky Quartz.—Every shade of these stones is easily obtainable. Some lemon-yellow varieties are much in request, and are often found. Very beautiful and water clear pieces are found up to one pound in weight. I have seen large blocks of perfect cairngorm from the deep leads at Gulgong. The fine group figured on the photograph exhibited, comes from a tin-bearing drift at Elsmore, near Inverell. The darkest of these stones becomes clear on heating. As exemplifying their abundance, I may say that my collection contains good smoky quartz from places as widely

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1 Geology of the Vegetable Creek Tin-mining Field, by Prof. T. W. E. David, p. 133.

separated as Kiandra, Gulgong, Tingha, Dubbo, Port Macquarie, Moruya, and Nundle.

Chrysoprase or green chalcedony occurs in a conglomerate overlying the coal measures at Gunnedah. It is rare ; I have but a single example in my cabinets.

Jasper is abundant in every part of the colony, the plains of the interior, granitic and Hawkesbury-sandstone country excepted. It is curious to note that rather good and rich-coloured jasper is found in the vicinity of Silurian limestones, particularly about Molong. Vast quantities are derived from a belt of rock that can be traced from Moonbi to Bingara. I have found good water-worn jasper ten miles east of Narrabri, have never seen any use made of this stone.

Chalcedony is abundant in the northern and western districts, but no really good examples have come under my notice. Remarkably fine slates of chalcedony mamillated on the upper surface are found near Walcha, but beautiful as they are they hardly come under the heading of precious stones.

Agate.—We are so accustomed to see beautiful agate in the shape of agate mortars, pen handles, and various ornaments—the work of the Oberstein mills—that we can only with difficulty class those hitherto found in New South Wales as precious stones. One is safe in saying that tons of agate could be collected at Werris Creek and Narrabri, but in every ton there would be not more than two or three specimens worth the attention of a collector, not to speak of a dealer in precious stones.

Serpentine.—Some at least of our serpentines deserve to rank as precious stones. Quite recently a serpentine of a rich leaf-green colour has been discovered at Whitney Green, near Orange. The rich colour of this stone is unique. But the slabs sent me were not more than a few inches square. Should any quantity of the material be available it will find a ready market.

There is a serpentine at Port Macquarie that might well be considered a precious stone, from its fine colour, texture, and

polishing properties. Very handsome slabs of serpentine can be procured in abundance at Bingera and Drake, the latter veined with chrysotile.

A variety of *Nephrite* or jade occurs at Lucknow in the Pro prietary mine. It is associated with a hornblendic felsite. Under the microscope it shows a beautiful felted structure that explains the wonderful toughness of this stone.

I have one specimen of *Iolite* found with topaz and tinstone at Emmaville. It is hardly fine enough to be ranked as a precious stone, but its presence is worth recording.

At Mount Hope an ore of copper is sometimes found consisting of a siliceous red oxide, green carbonate, and "grey ore." Pendants and trinkets of this were at one time in demand. This stone takes a good polish, and the colours are very clear. It might be called a precious stone but has an unmistakably vulgar appearance when placed alongside true gem-stones.

Some really good *Malachite* was found in nodules up to two inches in diameter in the upper levels of the Great Cobar Mine. The colour of these when cut was remarkably fine—darker and richer than the well-known Walleroo malachite. A fibrous variety, faultless in colour but too soft to polish, was also very plentiful at Cobar.

Notes on the Chemical Analysis.

Topaz.—Perfectly transparent stones were selected, and freed from any surface traces of iron, etc., by boiling in HCl. They were ground to the finest possible powder in an agate mortar, which was weighed before and after crushing. The SiO_2 taken up from the mortar was afterwards deducted. The mineral was fused with sodium and potassium carbonates, and the sodium fluoride formed was dissolved out of the melt with water. The solution was warmed with Am_2CO_3 to separate any small quantity of SiO_2 and Al_2O_3, and filtered.

The residue was dissolved in HCl, and the SiO_2, Al_2O_3, and CaO, separated by usual method.

The filtrate was boiled till free from ammonia and the greater part of the Na_2CO_3 neutralised with nitric acid. $CaCl_2$ was then added, and the precipitate of calcium carbonate and fluoride ignited to facilitate filtration. The $CaCO_3$ was dissolved out with acetic acid, and the CaF_2 dried and weighed.

Garnet—Pyrope.—These were picked out carefully from the gem-sand, crushed and sieved. The sample was fused with double carbonates, and the melt, which possessed a deep green colour, dissolved, and the $Si\ O_2$ separated.

The iron and alumina were separated by basic acetate method, re-dissolved and precipitated with NH_4OH, and the double oxide weighed. The ignited residue was fused with potassium bisulphate, and the iron estimated volumetrically. The filtrate from the above was made alkaline with NH_4OH, bromine water added, and boiled, and the precipitate weighed as Mn_3O_4. The filtrate was treated for CaO and MgO in the usual way.

The ferrous iron was estimated by decomposing the sample with repeated doses of HF in an atmosphere of coal gas, the residue dissolved and titrated with $K_2Cr_2O_7$.

Emerald.—The crystals were quite transparent, and perfectly free from any of the matrix, pulverised and fused with double carbonates; the mass which was faintly green was digested with HCl and H_2O, and the SiO_2 separated. The Al_2O_3 was precipitated from the filtrate after concentration by pouring it slowly into a strong solution of $(NH_4)_2CO_3$, the BeO remaining dissolved. This was allowed to digest several hours to ensure the complete solution of the BeO. The Al_2O_3 was filtered off, and after boiling off the $(NH_4)_2\ CO_3$ and acidulating with HCl, the beryllia was finally precipitated with NH_4OH as $Be(OH)_2$. This method of separating BeO from Al_2O_3 is stated in Crookes' "Select Methods" not to be reliable, but as a number of my experiments gave perfectly concordant results I have no reason to object to it. A spectroscopic examination was made of the residue, obtained in the usual separation of the alkalis. The rare

alkalis were carefully searched for but were found not to be present.

Basaltic Rock.—In the estimation of the alkalis, the double chlorides of sodium and potassium were weighed, then the Cl determined volumetrically. The proportion of Na and K was then calculated by the formula given in Thorpe. The K was also specially determined by the $PtCl_4$ method.

I am indebted to the following works in studying gems and precious stones :—

"Minerals of New South Wales."—Liversidge.
"Gems and Precious Stones."—Kunz.
"Precious Stones and Gems."—Streeter.
"Precious Stones."—Church.
"System of Mineralogy."—Dana.
"The Science of Gems."—Lewis Abbott.
"Select Methods of Chemical Analysis."—Crookes.
"Mineral Analyses."—Wöhner.
"Encyclopédie Chimique."—Fremy.

*Conclusion.

Diamond—New South Wales diamonds are characterised by (*a*) a high specific gravity ; (*b*) a superior hardness and a fine lustre ; (*c*) an absence of pronounced cleavage. Although some stones five to eight carats have been found, the bulk of the stones are small, three to the carat. The diamond is widely distributed but is found in three localities only, in quantities sufficient to be considered economically important :—Bingara ; Inverell district, including Cope's Creek, Round Mount, and Staggy Creek ; and Two-Mile Flat, near Mudgee. The original matrix of the diamond has not yet been discovered. The diamonds hitherto found occur in drift, and there is no evidence to show they were formed in these drifts. The probability is that the diamond is derived from a matrix occurring higher up the Dividing Range than any diamond bearing wash known at present.

Sapphire—Sapphires are found chiefly in the tin-bearing drifts of Tertiary and Post-Tertiary age of the Emmaville and Tingha

districts. There is reason to believe that basalt is the matrix of sapphire. The blue sapphire is abundant under the conditions mentioned. The bulk of the stones found are opaque, and stones of good quality are rare. Some bronze coloured and yellow opaque sapphire from the Berrima district are remarkable for their high specific gravity. The ruby is in New South Wales the rarest of our gems.

Emerald—Emeralds are found near Emmaville in a felsitic matrix associated with topaz, fluorspar, and tinstone. Emerald and beryl occur in the same district in a granitic matrix.

Topaz—Topaz of excellent quality is found in New South Wales. It occurs for the most part in the tin-bearing granites of the northern portion of the colony, and has been discovered *in situ*, but more abundantly in the tin-bearing drifts and recent detrital deposits.

Opal—Opal of excellent quality is found in Cretaceous beds in Western New South Wales. This opal is found to replace shells, belemnites and saurian bones of Cretaceous age. The silica for this opal has been derived from beds of organic origin—diatomaceous or radiolarian. Opal is also known to fill the cavities in lavas, the silica of these gems being derived from the decomposition of the felspars.

Other Gems—Zircon is abundant in a few localities, and in lesser quantity is to be found in drifts over granitic and lower Palæozoic areas. Garnets are abundantly distributed, but stones that may rank as gems are known from a few districts only.

From a scientific standpoint it will be seen that the variety of our known gem-stones is sufficient to attract attention, and open up a subject worthy of more elaborate research. From a commercial point of view we may easily believe that the gems, and precious stones of the Colony form not an inconsiderable item amongst the factors that go to make up the grand total of the Colony's magnificent heritage—her mineral resources.

*Notes on the Discrimination of Gems.

In view of the fact that this paper will be read by prospectors and others in far-off districts, I venture to add a few notes on the discrimination of gems.

In my own experience, I find it a common occurrence to have lustrous quartz crystals mistaken for diamonds; and numbers of practical men fail to distinguish between topaz and quartz. Another every-day difficulty is to discriminate between white zircon and diamond. On these points, therefore, I append some notes, intended for those who are so situated as not to have the methods and resources of a laboratory at their disposal.

Laboratory methods for the determination of gems have now reached great perfection, so much so that the mineralogist is not now forced to determine the hardness of a gem, as a necessary process in establishing its specific identity. Mr. Lewis Abbot, says, in one of his lectures, that "we can begin by dismissing hardness as a character which it is really necessary to determine, except to identify the diamond or to distinguish a real stone from a paste; here I know I shall earn a rebuke from the orthodox mineralogist, who, in order to pursue the study of what should be a peaceful science, arms himself with a knife and proceeds to scratch everything which he comes across."

In the laboratory where accurate observation is possible, the optical properties and specific gravity will give data sufficient to determine most gems. The use of heavy solutions that float many gem-stones is now a recognised method. The reflecting goniometer, the polariscope, the stauroscope, the dichroscope, and the total reflectometer are also used to discriminate between gems. The prospector, however, cannot avail himself of the precision that these instruments make possible, and he is compelled to fall back on the hardness, colour, fusibility, specific gravity, and perhaps the crystalline form of supposed gem stones.

Diamonds.—Zircon is most commonly taken for diamond by prospectors. The parcels of diamonds sent from Bingara very

often contain some zircon. The mistake is a pardonable one, for the surface lustre of these stones is often finer than that of a diamond, and as is well known, the specific gravity of the zircon is 4·7, while the diamond has a specific gravity of 3·5 only.

To distinguish between these stones the prospector will try if the supposed diamonds will cut glass. As a zircon when used to advantage will scratch glass easily, while a true diamond will not mark glass if a rounded face is drawn along the glass. Serious mistakes are thus apt to occur. Quite recently money was lost and much suffering caused through a "find" of white zircons near Nundle being mistaken for diamonds.

In diamond bearing country I should advise a prospector to carry a small plate of sapphire and a splinter of diamond mounted on the end of a short length of stout brass wire. This last is known as a writing diamond. The sapphire plate and the diamond should not cost many shillings.

The supposed diamond is set in the end of a stick of sealing wax, and while the wax is softened by heat the stone can be so arranged that a sharp solid angle or a edge projects. This can be done after a little practice by heating the stone, and quickly transferring it to the wax. Holding the stick of sealing wax, the stone to be tested is rubbed with a gentle pressure round and round, on the polished face of the sapphire plate. Not more of the sapphire need be used than the space covered by a pin's head. After the friction is continued for half a minute, if the sapphire plate has lost its polish, and with a lens shows the point of contact "eaten into" or "burned," the stone being tested is a diamond, since the diamond is the only stone that can cut into a polished plate of sapphire.

The use of a writing diamond will however settle the matter at once. If a prospector draw a writing diamond over a smooth zircon and over an uncut diamond, the difference will be so apparent that there can be no room left for doubt. Even with a very gentle pressure the writing diamond "catches" or "drags"

on the zircon, and a dull cutting noise is made. When the writing diamond is gently rubbed on a real diamond, it (the writing diamond) does not "bite" but glances and slips off in every direction, no friction due to cutting being apparent, and the sound produced is metallic-like and sharp.

It may be well to remember also that where zircons are found a considerable number of the stones are red, or some shade of red, and on heating, these coloured stones become white and remain white on cooling. Red or green diamonds are exceeding rare. These rough and ready tests will also distinguish between small and waterworn topaz and diamond—stones which also are confused by prospectors.

Topaz.—Clear waterworn quartz pebbles are continually mistaken for topaz. The simplest and most convenient test for a prospector is, when these stones are abundant, to break one and note the high and perfect polish on the flat cleavage faces of the topaz. Quartz of course *never* breaks to show lustrous flat cleavage faces, but rather with irregular curved surfaces not unlike the fracture of common bottle glass.

When crystals are found it may be noted that the topaz is striated and grooved up and down *along* the length of the prism, while quartz is striated *across* the prism.

A splinter of topaz mounted after the fashion of a writing diamond will in a moment distinguish between topaz and quartz, the topaz scratching quartz with ease.

Heavy solutions are now so easily procurable that they may be of service to miners. Klein's solution of borotungstate of cadmium has a specific gravity of 3·28, therefore every gem with a lower specific gravity will float in this liquid. If a white beryl, a topaz, a quartz and a diamond are placed in this liquid, the quartz and beryl will at once float, while the diamond and topax will sink. In Klein's solution—

will sink—diamond, sapphire, ruby, topaz, spinel, garnet, zircon.

will float { quartz, cairngorm, amethyst, moonstone, emerald, beryl, aqua-marine.

It may be noted in general that stones that will not scratch glass (opal excepted) are useless as gems. Also that stones that fuse easily before the blowpipe are as a rule worthless.

I would repeat that these notes are not intended to replace the directions found in so many miners' handbooks, but rather to supplement what they deal with. There is no difficulty in distinguishing gems when instruments and scientific apparatus are at hand, and these notes may be of service when such help is not available.

Explanation of Plates.

Plate XIII.

Fig. 1—Two crystals of topaz from New England. Natural size. The rounded and waterworn example is 3,136 grains in weight, and perfectly clear and pellucid throughout. There is hardly more than a trace of blue-green, more pronounced towards one end, in the stone. The pleochroism is however very marked. This specimen is so evenly abraded that not a trace of the basal cleavage can be seen, rather a remarkable feature for so large a stone with so perfect a cleavage. The "Maxwell-Stuart" topaz, said to be "the largest cut precious stone known,"[1] weighs 1475 grains. The specimen figured should cut into an excellent stone to turn the scale at 1800 grains.

Fig. 2—The crystal shewn on the same plate is characteristic of the habit of the larger topaz, that are found over the granitic areas of the New England. Prismatic and pyramidal faces are well developed. But the brachydomes *f* are so prominent as to give a wedge-shape to the crystal when it stands on the traces of the basal cleavage. This specimen weighs 3,063 grains. It is marred by several feathers, so that the stone could not be cut into one large gem. *a*, brachydomes; *b*, pyramid; *c*, *c*, prisms.

Fig. 3—A crystal of topaz found in a granitic detritus, Oban, New England. Natural size. This fine crystal weighs 6,839 grains and has a decided blue tint with a cloud of amber-brown, filling about one-fourth of the specimen towards the centre. The basal cleavage in this example is perfect. The prisms and pyramids are striated. The wedge-shaped appearance of the crystal is due to the great development of the brachydomes.

Plate XIV.

Fig. 1—Topaz shewing perfectly water-worn and rounded specimens. Natural size. Vegetable Creek, New England.

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[1] Min. Mag. Vol. III., p. 95.

Fig. 2—Topaz, shewing a parcel as usually placed on the market. They are of first quality, and represent the choice specimens from at least twenty times their weight of inferior material. Photographed natural size.

Plate XV.

Fig. 1—At the Emerald Proprietary Mine patches of kaolin are found in which are embeded long slender crystals of beryl and aqua-marine, sometimes deep enough in colour to come under the heading of emerald. The plate shews the appearance and habit of these crystals. Photographed natural size.

Fig. 2—Beryl, aqua-marine and emerald from various localities on the New England tableland, re-produced natural size. They were all found in working alluvial deposits for tinstone.

Plate XVI.

Fig. 1—Diamonds found at Bingara. Natural size. As stated in the text, much larger stones are often discovered, but the photograph shews the average samples sent from Bingara.

Fig. 2—Sapphire as found in the tin bearing drifts in the district around Emmaville. Natural size. The crystals are for the most part blue, but nine of those figured are green. Some of the examples are banded alternately in white and blue. A few honey-yellow crystals are tipped with blue. Some of the stones shew the corosion lines referred to in the text.

Plate XVII.

The bulk of the Queensland opal comes to market embedded in a hard ironstone matrix as shewn in Fig 1, while *all* the White Cliffs opals are found in a friable and easily pulverulent matrix, and are sent down quite free from matrix, as shewn in Fig. 2. Both figures natural size.

Plate XVIII.

Fig. 1—Tin sluicing boxes, Emmaville. Sapphire is saved in these sluice-boxes.

Fig. 2—A cradle used in gold saving, Tumberumba Creek. Sapphire is recovered by these machines.

Plate XIX.

Fig. 1—Opal mining at White Cliffs, N. S. Wales. The pillars left standing contain quite as much opal as the country removed. The pillars have been left for the same reason that some coal is left standing in a coal mine, to support the roof.

Fig. 2—General aspect of diamond bearing country at Bingara.

Plate XX.

Fig. 1—Highly inclined Silurian slates Sturt's Depôt Glen, N.S. Wales. The principal gems found in the west and north-west of the colony are opals and garnets. These stones occur in Cretaceous and Silurian country respectively. The plate shews the contrast presented by Silurian and Cretaceous country.

Fig. 2—Cretaceous escarpment between Tinaroo and Tibooburra, N. S. Wales.

NOTE—* Paragraphs or sentences preceded by an asterisk have been added since the reading of the paper.

DISCUSSION.

Mr. HENRY G. SMITH, said :—Mr. President, I would like to make a few remarks on portions of this paper, as there are certain statements contained therein that should not go unchallenged, and that are certainly open to criticism. I may mention that the time to prepare my notes has been very short, as the copy of the paper only came to hand this morning. First, under the section *Ruby*, the statement is made that "The best stone from these drifts was in the possession of Mr. Milner Stephen. It weighed within a fraction of one carat, was perfect in colour, but showed a feather on the templet." Mr. Stephen's collection of gem stones is now the property of the Government of New South Wales, having passed into the possession of the Technological Museum. In my capacity as Mineralogist to that Institution, the duty of determining the accuracy of the naming of the specimens in that collection, has devolved upon me. In it was a cut stone from this locality (near Mudgee), said to be a ruby, weighing over one carat, and which stone I presume is the one referred to in the paper. This was found on investigation not to be a ruby, but a topaz. In colour it resembles the burnt topaz, obtained by heating the dark wine-coloured topaz of South America, it has a specific gravity of 3·51 and its hardness is 8, it being readily scratched by a sapphire. The methods whereby gem stones are determined to-day, are perhaps, more accurate than those in use when Mr. Stephen's specimens were named, but the question arises whether

other comparatively large so-called rubies stated to have been found in this colony, are of the same character as this specimen, and therefore topaz. The theory of the occurrence of these topazes, having this colour peculiar to burnt topaz, found in this locality, (because we have no reason to doubt the authenticity of this specimen in that respect), is, that the topazes have been altered to their present colour by the heat of the overlying basalt. That authentic rubies do exist in the neighbourhood of Mudgee is undoubted; in Mr. Stephen's collection some specimens from that locality were determined by myself, and the results published in my work.[1] They are however, very small, being mere fragments.

Passing on to the article on *Topaz*, we find an analysis given for topaz from Emmaville. From the figures therein given, it is not possible to obtain the theoretical formula for topaz, as given by any recognised authority. We find placed by its side an analysis of a topaz from Tasmania for comparison. The percentages there given, however, by Dana, work out almost to the theoretical quantity required. A perfect specimen of topaz often gives nearly the theoretical percentages, and when a difference in some of its constituents, of three or four per cent. is obtained, it is better that the analysis be not published. It is to be regretted that New South Wales topaz should by this analysis give results so removed from the theoretical requirements. There is nothing gained by publishing results or data collected, that do not somewhat advance our scientific knowledge, by enabling us to arrive at a just decision, as to the actual molecular constitution of the mineral.

Passing on to the article on *Garnet*, we find that pyrope is announced, and the analysis given. The Rev. J. M. Curran will remember, that some months ago I stated to him, that from rough tests I found that these stones were not pyrope. I will now show from the percentage constituents as given in the analysis, that

1 "Gems and Precious Stones," Technical Education Series, No. 11, p. 6.

these garnets cannot be pyrope. Taking the recognised classification of the garnet group, we find that pyrope is a subdivision where magnesia predominates in atomic proportions over the other protoxide bases; or, that the ratio is at least $\dot{M}g : \dot{C}a : \dot{F}e + \dot{M}n = 3 : 1 : 2$, or that $\dot{M}g$ equals the other protoxides, or the ratio is as 1 to 1. In an analysis published by Dana, and stated to be of high merit, it is as 1 to ·87. But if we take the analysis of the so-called pyrope given in the paper, we find that the ratio is $\dot{M}g : \dot{C}a + \dot{F}e + \dot{M} = 3 : 6{\cdot}18$ or a ratio of 1 to 2 as shown by the figures given. Taking the protoxides only, the oxygen ratio works out as follows:—

		ratio	
FeO = 10·04%	contains oxygen =	2·23 = 1·911	
MnO = 3·76 ,,	,, ,, ,,	0·85 = 0·729	= 6·18
CaO = 14·45 ,,	,, ,, ,,	4·13 = 3·540	
MgO = 8·76 ,,	,, ,, ,,	3·50 = 3·000	= 3

On behalf of mineralogical science in New South Wales, I object to priority being given for pyrope to a garnet with a composition so diverse from that required to form the species. If pyrope is announced, it should be for a garnet that by its percentage composition, shows legitimate claim to the name. The garnets from the sandstone at Sydney, described by myself in the proceedings of this Society two years ago, contain more magnesia than those in this paper, yet by no stretch of imagination can they be construed into pyrope. If we are to adhere to the oxygen ratio for this class of silicates, we must take some notice of the recognised basis on which these species have been formed, and not attach names to minerals merely because they *approach* others in some constituents. It is evident therefore that on a scientific basis *these garnets are not entitled to be considered as pyropes.* In the classification of the garnet group into its several subdivisions, sufficient latitude is given, by recognised authorites, for foreign constituents that exist more or less in all garnets, but this limit cannot be recklessly ignored.

Professor David wished to know the evidence on which the statement, made by the Rev. J. Milne Curran, was based that

Australian diamonds were harder than Cape or Brazilian diamonds. If the statement was correct, the refractive index of the Australian diamonds would probably be found to differ from that of Cape and Brazilian diamonds. Had the refractive index of Australian diamonds been determined? With regard to the important discovery by the Rev. J. Milne Curran of sapphire *in situ* in the basalts near Newstead, in the Inverell district of this Colony, he wished for further information as to whether (1) More than one specimen of sapphire had been found imbedded in the basalt at the above locality; and (2) As to whether the sapphire in the basalt showed any evidence of having possibly deen picked up by the basalt from alluvial gravels over which the basalt had flowed. With regard to the occurrence of turquoise near Bodalla, he would like to know whether any trace of phosphatic limestones or phosphatic rocks of any kind had been met in the same locality. As to the mode of origin of the precious opal in Australia, while he agreed with the suggestion made by the Rev. J. Milne Curran that it was possibly diatomaceous, he was inclined to think that in view of the latitudes of the opal-bearing localities, and of the association, near White Cliffs, Wilcannia, N. S. Wales, of marine shells with the opal rock, that radiolaria had probably played an even more important part in supplying material for the opal than diatoms. Sections of the opal rock, kindly lent him by the Rev. J. Milne Curran to examine for radiolaria showed fairly good evidence of the presence of remains of these organisms in the form of spherical casts of the interior of the radiolarian shells. No definite latticed shell had, however, been as yet detected by him. He had observed similar spherical casts in some of the opal rock from Queensland. They were just the right size for radiolaria, but too large for diatoms. He understood that the Rev. J. Milne Curran was quite prepared to admit the possibility or even probability that the opal of Australia derived its silica largely from radiolaria. He considered that the Society were to be congratulated on having presented to them an essay containing such important original observations as those made by the author as

to basalt being the true parent rock of the sapphire, and he had much pleasure in moving a hearty vote of thanks to the Rev. J. Milne Curran for his Prize Essay, and for the trouble he had taken not only in reading and explaining it to the members, but also in illustrating it by means of specimens and an excellent series of photographs.

Rev. J. M. Curran in reply, said:—Mr. Smith's remarks are such that a more satisfactory reply could be given if his views were put in writing: these, with the reply could then be printed with the paper.

With regard to Professor David's remarks, I think there can be no doubt that the Bingara diamonds are harder than Cape stones. Cutters are aware of the fact that diamonds from different localities differ in hardness. We have Mr. Streeter's estimate in the paper, of the extra time required to polish Bingara diamonds. A well known diamond cutter, Mr. L. Claremount, writing in the *S. M. Herald*, of December 5th, 1896, gives it as his opinion based on a working knowledge, that Australian diamonds are harder than any others. The refractive index of our diamonds has not been determined so far as I am aware. As to the sapphire, several specimens have been found at various times. I had two examples, and saw a fine specimen with Mr. Brierton Senr., Armidale. There was no evidence to point to the likelihood of the basalt having picked up the sapphire from the gravels over which it flowed. Had this been the case, other stones should also have been picked up and found embedded in the basalt. The basalt showing the sapphire is neither ropy, vesicular, or glassy, as if it were in contact with underlying rocks. On the contrary, it is of the usual compact crystalline type, at the same time it is "peculiar" enough to do no violence to accepted views in making it a matrix for sapphire. The phenocrysts of magnetite[1] and pleonaste make the rock distinctive without departing from the common type of New England basalts.

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[1] Dana notes that the fine sapphires found in the beds of rivers are accompanied by grains of magnetite.—Descript. Mineralogy, 6th edit., p. 212.

Personally I have no doubt that the sapphires have come from basalt. The serious objection to this view is the occurrence of sapphire in the drifts under basalt. Sapphire is recorded as being associated with the diamond on the Cudgegong and at Bingara,[1] and as the diamonds are derived from drifts that underlie basalt, the inference is that sapphire is also found in drifts under basalt. This is a difficulty that must be faced, and the explanation may lie in the fact that it is in redistributed drifts only the sapphire is found. At Tumberumba I never saw a trace of sapphire in the wash from the "deep ground" under basalt. The sapphires I saw were all found in pleistocene drifts that must have received detrital matter from the degradation of basaltic hills.[2] From the evidence before me I have no doubt as to the matrix of the sapphire, but it would be premature to say the question is settled absolutely. There is room for much more research, and another explanation may be forthcoming for the facts placed on record.

Referring to the turquoise, I am not aware of any phosphate-bearing rocks near Bodalla, and it might be said that the rarity of phosphatic rocks is somewhat remarkable in this colony. It is very satisfactory to hear that Professor David has detected radiolarian casts in "angel rock" from White Cliffs, the slides I handed him being slices of that rock, already described in the text. The views expressed may however be left on record for this reason: the opals found in New South Wales except at White Cliffs can be traced to igneous rocks the decomposition of whose felspars supply the silica. After an examination of the White Cliff mines, I saw that there were no igneous rocks in the locality, and the opal was associated with the peculiar sedimentary lenticular shaped rocks locally called angel-stone. This had many of the characters of an indurated diatomaceous earth, and suggested

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1 Liversidge—Minerals of New South Wales, pp. 237 and 241.

2 Bernhard von Cotta states that sapphire occurs as an original product in the basaltic lava of Niedermendig on the Rhine.--Rocks Classified and Described, Revised Ed. p. 8. Specimens from this locality are not uncommon in Museums.

a diatom ooze as the source of the silica. The probability is that it was a radiolarian deposit. But this fact stands out, that at White Cliffs, shells, belemnites, etc., are converted into noble opal by a silica derived from organic sources, and at Rocky Bridge Creek a noble opal is found, filling vesicular cavities in an andesitic trachyte, and its silica is derived from decomposing felspars. The points raised by Professor David were most important, but the complimentary tone of his remarks could not make the author forget that there is necessarily much debatable matter in a paper covering so much ground.

Mr. Henry Smith's criticism contains much compressed into a small space ; it will be better to take his statements seriatim, so as to prevent any confusion of ideas. Mr. Smith's remarks are also so incisive, although to a less extent than in their original form, that anything short of direct reply would hardly meet the case.

Mr. Smith—"Mr. Stephen's collection of gem stones is now the property of the Government of New South Wales, having passed into the possession of the Technological Museum."

Reply—In this statement Mr. Smith is in error, as Mr. Stephen's collection—probably the finest made in Australia—was broken up and sold. Dr. Bleasdale of Melbourne purchased the best rubies and sapphires. Part of the original collection is now in my cabinets, other parts of it were sent to London. There is it is true, a small collection of gems, made by Mr. Milner Stephen in the Museum of the Technical College. They were sent there from my laboratory. This collection had passed from Mr. Stephen's possession many years ago, and was in the hands of dealers for some time, finding its way finally to the Australian Joint Stock Bank, from whence I got it in a state of complete disorder. The replacing of many of the labels and the disposition of the specimens, was due to the good offices of my laboratory attendant—an enterprising youth whose ambition seems to have been, to find a specimen for every label !

Mr. Smith—"In it (the collection) was a cut stone from this locality, near Mudgee, said etc."

Reply—I described a stone as—(1) a ruby, (2) under a carat in weight; (3) perfect in colour; (4) showing a feather on the templet.

Mr. Smith has assumed, I submit unwarrantably, that this refers to—(1) a topaz, (2) weighing over a carat; (3) poor in colour (burnt topaz); (4) showing no feather on the templet.

Mr. Smith—"It has a specific gravity of 3·51 and its hardness is 8, it"—the cut stone—"being readily scratched by a sapphire. The methods whereby gem stones are determined to-day are perhaps more accurate than those in use when Mr. Stephen's specimens were named."

Reply—Mr. Stephen never professed to be a mineralogist. He did good service in locating gems. His work was often faulty, but he made no claim to be considered a scientific man. Nevertheless he would not have left it on record, that a "cut stone" was readily scratched by a sapphire! The tests—those mentioned by Mr. Smith—are not in advance of the methods that prevailed long before Mr. Stephens time. Mr. H. A. Miers in one of his lectures says that "incredible as it may seem, the estimation of hardness and specific gravity are the only attempts at anything like scientific measurements ever made in the ordinary course of business applied to stones." He goes on to say:—"We can begin by dismissing the hardness as a character which it is really unnecessary to determine, except to identify diamond or to distinguish a real stone from paste; here, I know, I shall earn a rebuke from the orthodox mineralogist, who, in order to pursue the study of what should be a peaceful science, arms himself with a knife and proceeds to scratch everything which he comes across." Yet these methods are those advanced by Mr. Smith in a critical notice.

Mr. Smith—"The question arises whether other comparatively large so-called rubies stated to have been found in this colony are of the same character."

Reply—I am not aware that statements to this effect have ever been made. There are not more than a dozen observers who, of their own knowledge, dealt with the occurrence of the ruby in this colony, and not one of them has ever published a line about "other comparatively large rubies stated to have been found in this colony." They all agree that the ruby is the rarest of our gems.

Mr. Smith—"The theory of the occurrence of these topazes, having this colour peculiar to burnt topaz found in this locality, is that etc."

Reply—I am not concerned with the theory as to the cause of colour in these stones, but would observe that the amazing statement is made that burnt topaz is found with the ruby at Two Mile Flat. The record of this locality for "burnt" topaz is certainly new to science; I have reason to doubt its accuracy. Professor Alex. Thomson, an accomplished analyst, spent some weeks at Two Mile Flat, but made no record of "burnt" topaz in his paper on the occurrence of the diamond near Mudgee. Mr. Norman Taylor an experienced field geologist, spent some months at the same place,[1] but makes no mention of "burnt" topaz either in his paper read to this Society, or in his subsequent papers in the Geological Magazine. May I add that I have seen many hundred of specimens from the diamond bearing country near Mudgee, but up to the present I have not noted a "burnt" topaz. Mr. Smith does not indicate whether he spent any time in examining this district, neither does he quote any authority. He nevertheless states what, as far as I am aware, no one else has ever heard of. I venture the opinion that this is going beyond the province of legitimate criticism. Surely Mr. Smith does not depend for his information on the little collection of Mr. Stephen's that was in my keeping when purchased from the Australian Joint Stock Bank by the Department of Public Instruction. The "burnt" topaz in that collection is a South American stone.

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[1] Geological Magazine, Dec. II., Vol. VI., p. 400.

Mr. Smith—"That authentic rubies do exist in the neighbourhood of Mudgee is undoubted; in Mr. Stephen's collection some specimens from that locality were determined by myself."

Reply—This is a plain statement of fact, but it is also true that twenty-six years ago Prof. Thomson found rubies at Two Mile Flat, near Mudgee, and actually published an analysis of them,[2] and to him therefore is due the credit of first determining "that authentic rubies exist in the neighbourhood of Mudgee."

Mr. Smith—"From the figures therein given it is not possible to obtain the theoretical formula for topaz."

Reply—That is so obvious as to render discussion unnecessary. Divergences of the sort are found in the work of some of the most eminent analysts.

Mr. Smith—"When differences of three or four per cent. are obtained it is better that the analysis should not be published."

Reply—This statement is an expression of opinion only—an opinion with which I cannot agree. As opposed to it, it may be noticed that Genth, Wachtmeister, Delesse, and Liversidge have published analyses where "differences of three and four per cent. are obtained." For example in Vol. XXIX., p. 324 of this Society, just issued, Professor Liversidge gives an analysis of topaz from Shoalhaven, which differs *more* than three or four per cent. from theoretical requirements. Here are the figures—

Analysis of Topaz.

	My results		Theoretical requirements.		Prof. Liversidge.
SiO_2	30·29	...	35·3	...	28·19
AlO_3	60·90	...	56·5	...	62·66
CaO	·40				
F	15·05	...	17·6	...	14·01

I am content to follow in the footsteps of analysts, whose scholarship and technical skill is beyond dispute, and consequently venture to publish my analysis, notwithstanding Mr. Smith's declaration that this "should" not be done.

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[2] Trans. Roy. Soc. N. S. Wales, 1870, p. 191.

Mr. Smith—"There is nothing gained by publishing results or data collected that do not somewhat advance our scientific knowledge, by enabling us to arrive at a just decision, as to the actual (sic) molecular constitution of the mineral."

Reply—If anyone is able to reach a "just decision as to the actual molecular constitution" of a mineral it may be said that the blue ribbon of science is assuredly his. An insight into the "actual molecular constitution" of minerals would of course enable us to express the functions of the aluminates in mineral formulæ. No analyst ever hoped for such a possibility in the present state of our knowledge. Indeed if Mr. Smith's views on this matter were commonly accepted, not a single analysis of a mineral would have been published during this century.

Mr. Smith—"The Rev. J. M. Curran will remember that some months ago I stated to him, that from rough tests I found that these stones were not pyrope."

Reply—I do remember. The information however could not affect my results. My paper was at the time in the possession of the Royal Society, and in any case the statement would not be of service to me as I do not rely upon rough tests. If a rough test satisfied Mr. Smith that the stones were not pyrope, he is now arguing for a foregone conclusion.

Mr. Smith—"Taking the recognised classification of the garnet group we find that pyrope is a subdivision where magnesia predominates over the other protoxide bases . . . or that Mg (sic) equals the other protoxides, or the ratio is as 1 to 1."

Reply—I understand Mr. Smith to mean that a standard for pyrope is, that the MgO must be related to the other protoxides as 1 to 1. Almost in the same breath he says the ratio is at *least* 1 to 1. Let us therefore take some analysis of pyrope, and see if they will mould themselves to Mr. Smith's standard. The figures are based on Fe 56, O 16, Mn 55, Mg 24·3, Ca 40.

1. Protoxides from an analysis of a pyrope by Knap, *vide* Dana's Descript. Mineralogy, Sixth Ed. p. 441.

FeO	= 18·70 %	contains oxygen	4·15	
MnO	= ·58	,, ,,	·13	
CaO	= 5·02	,, ,,	1·43	= 5·71
MgO	= 12·00	,, ,,	4·76	= 4·76

4·76 and 5·71 are not in the ratio of 1 to 1. Here the MgO gives an oxygen ratio *less* than that of the other protoxides.

2. Protoxides in an analysis of pyrope given in Streeter's Precious Stones, 5th ed., p. 288.

FeO	= 9·5 %	contains oxygen	2·11	
MnO	= 2·5	,, ,,	·56	
CaO	= 5·0	,, ,,	1·42	= 4·09
MgO	= 15·0	,, ,,	5·95	= 5·95

These figures also will not give a ratio of 1 to 1.

3. Protoxides from an analyses of pyrope by Prof. M. Forster Heddle, Trans. Roy. Soc. Edinburgh, Vol. XXVIII., p. 311.

FeO	= 8·11 %	contains oxygen	1·8	
MnO	= ·46	,, ,,	·1	
CaO	= 5·04	,, ,,	1·44	= 3·34
MgO	= 17·85	,, ,,	7·08	= 7·08

The figures 7·08 and 3·34 likewise do not give a ratio of 1 to 1.

4. Protoxides from an analysis of pyrope by Kobel, *vide* Lewis Abbott's Lectures on the Science of Gems.

FeO	= 9 %	contains oxygen	1·99	
CaO	= 2	,, ,,	·57	= 2·56
MgO	= 10	,, ,,	3·97	= 3·97

There is only one conclusion to be reached. If Mr. Smith's standard is worth anything, Dana and Knap do not know what constitutes a pyrope. Dana's Systematic Mineralogy is in its sixth edition, and is a standard work. Under the heading PYROPE Dana gives thirteen analyses. One of these shews that the ratio between the oxygen in the MgO, and in the other protoxides taken together is as 4·76 in the MgO, to 5·71 in the other protoxides together. These figures will not give a ratio of "1 to 1" or even "at least" 1 to 1. According to Mr. Smith's standard it "cannot be pyrope." I must prefer to be guided by Dana.

The example No. 3 shews the opposite extreme. Here again, it is simply a question of being guided by one of two masters. I decide for Professor Heddle.

I should like to add that oxygen-ratio (quantivalent ratio of modern chemistry) first introduced by Bischof in quoting mineral analysis, is of great utility under certain conditions. It helps in calculating the *mineral* percentages in a rock. It is of use in that process, dear to junior analysts, of balancing protoxides against sesquioxides, and the protoxides and sesquioxides against silica. But it is of no value when used as Mr. Smith uses it amongst the protoxides themselves (which of course are isomorphous) to prove that a garnet is *not* a pyrope. The calculation of oxygen ratios looks imposing on paper, but instances have come within my ken, where this affectation of precision has afforded shelter for the issue of material of doubtful value.

In making a copy of my original paper the figures for the CaO and the MgO were transposed by a clerical error, but it will be noted I am not going into the figures of the analysis in any shape or form. I object to the standard set up by Mr. Smith.

Mr. Smith—"If we are to adhere to the oxygen ratio for this class of silicates."

Reply—Why should we adhere to it? Prof. Heddle, Dana, Knap and a host of others do not adhere to it. We all adhere to the legitimate use of the oxygen ratio. It is not a legitimate use of the method to use it exclusively amongst protoxides to prove a certain garnet is *not* a pyrope.

Mr. Smith has something to add about "recklessly ignoring limits." Here is how I learned that the stones in question were pyrope.

1. They occurred in a basic rock, and under the microscope, in thin slices this rock shows the radial structures called kelyphite shells by Rosenbusch surrounding the garnet. They show exactly the structure figured by Rosenbusch in his Microscopical Physiography, plate xiv., fig. 4 (Translation by Iddings). The garnets

occurring under conditions so like ours are decided by Rosenbusch to be *pyrope*.

Diller describes exactly similar shells around a *pyrope* in a basic rock from Elliott Co., Ky. The probability is that our garnet is a pyrope.

2. An analysis of the garnet showed the composition to be—

SiO_2	=	39·57
Al_2O_3	=	23·68
Fe_2O_3		·18
FeO		10·04
MnO		3·76
CaO[1]		8·76
MgO		14·45

3. I then took the table of garnets given by Dana—

Group I. *Aluminium Garnet*—

1. Grossularite—Calcium-aluminium garnet.
2. Pyrope—Magnesium-aluminium garnet.
3. Almandite—Iron-aluminium garnet.
4. Spessarite—Manganese-aluminium garnet.

Group II. *Iron Garnet*—

5. Andradite.
6. Ordinary Garnet.

Group III. *Chromium Garnet*—

7. Uvarovite.

Our garnet cannot possibly, from the analysis, belong to Groups II. or III. In Group I. we have four garnets.

The Bingara garnet has only

·58% of MgO; — It is not Spessarite which has 14 to 40% MgO;

and only 8·76 of CaO; — It is not Grossularite which has 24 to 36% CaO.

and only 10·04 of FeO. — It is not Almandine which has 20 to 35% of FeO.

[1] The figures for CaO and MgO were transposed in the proofs handed to the members generally. I handed corrected proofs to those more directly interested.

For lines 27, 28, and 29, page 284, substitute :—

The Bingara garnet has
14·45 of MgO ;

It is not SPESSARITE, which
has only 0·2 to 2·5 MgO ;

It comes under the heading pyrope ; probably is pyrope.

The specific gravity, colour, analysis, and the mode of occurrence all agree with pyrope. The specimen is pyrope.

This method may be faulty, but it is given in detail, as a charge of "recklessly ignoring" is one not often heard in scientific circles. It will be for others to judge if the above process smacks of recklessness. I would conclude by saying that I value highly the privilege and right of every member of our Society to criticise papers placed before the members. But criticism of the kind to which I have now replied, surely goes beyond that limit of dispassionate and courteous treatment which we have all a right to expect.

SILL STRUCTURE AND FOSSILS IN ERUPTIVE ROCKS IN NEW SOUTH WALES.

By Professor T. W. EDGEWORTH DAVID, B.A., F.G.S.

[*Read before the Royal Society of N. S. Wales, November 4, 1896.*]

Introductory.—Sill structure has long been known to play an important part in the architecture of the earth's crust. The development, however, of sill structure in New South Wales is so wonderfully extensive and complex as to justify a special description, inasmuch as it promises to revolutionize prevalent ideas, at all events in Australia, as to the nature of the junction line between eruptive rocks and sedimentary rocks, and satisfactorily explains the apparent anomaly of the occurrence of fossils in eruptive rocks. I propose therefore to offer a short preliminary note on this subject.

Bibliography.—Professor Judd has described sill structure in the Mesozoic rocks of Scotland.[1] Reyer has described in detail

[1] "On the Ancient Volcanoes of the Hebrides and the Relations of their Products to the Mesozoic Strata.—Quart. Journ. Geol. Soc. 1874, xxx., p. 220 – 300, pl. xxii. – xxiii., and Abstract in 1878, Vol. xxxiv., pl. xxxi.

the extensive sills of Mount Venda in the Euganean Hills.[1] G. V. Rath and others have at an earlier date described the same district.[2] Topley and Lebour have described the Whin sill of Northumberland, which may be taken as the type of a sill on a large scale.[3] According to the description given by the above authors the Whin sill covers an area of from one hundred and twenty to one hundred and thirty Km., and attains a thickness of eighty-four feet and upwards. It cuts obliquely across the planes of bedding, so that it has a vertical range of over 1,700 feet. Sir A. Geikie has described the extensive sills of the Western Isles of Scotland.[4]

In Australia Mr. E. F. Pittman has described some interesting rocks from Hill End, which from their close resemblance to the Mandurama and Tamworth rocks of this Colony, as regards mode of occurrence, I have no hesitation in classing as sills.[5] He says, (*op. cit.* pp. 1—2), "The siliceous slates and sandstones appear to be quite unfossiliferous, but obscure impressions of spirifera, encrinites, and corals *(Favosites)* are rather plentiful in the metamorphosed conglomerates. This latter rock forms one of the most noticeable features of the district. In the physical peculiarities of its occurrence it somewhat resembles the diorites which are characteristic of the neighbouring gold-fields of the upper Turon (Sofala), standing out on the hill tops in huge rounded masses, and showing a somewhat bomb-like or concretionary structure when quarried. Here, however, the similarity ends, for the Hill End rock, on close inspection, is found to be free from hornblende, and consists of quartz and felspar crystals in a blue silico-felspathic

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[1] Die Euganäen, Bau und Geschichte eines Vulcans, 8° 1877.

[2] Geognostische Mittheil. über die Euganäischen Berge bei Padua, Zeitschr. Deutch. Geol. Ges. 1864, XVI., S. 461 – Taf. XV. – XVI.

[3] On the Intrusive Character of the Whin Sill of Northumberland.—Quart. Journ. Geol. Soc. 1877, XXXIII., pp. 406 – 421.

[4] Trans. Roy. Soc. Edinburgh (1888) Vol. XXXV., p. 111, and Q.J.G.S., Vol. LII., 1896, p. pp. 373 – 381.

[5] Annual Report Department of Mines, Sydney, 1879. Notes to accompany Geological Map of Hill End and Tambaroora.

matrix, while indistinct outlines of large pebbles of slate and sandstone clearly point to the fact that it is an altered sedimentary rock, the rearrangement of the particles with the production of the crystals of felspar and quartz being due partly to chemical action, and partly to heat and pressure caused by the shrinkage of the earth's crust."

Mr. C. S. Wilkinson, the late Government Geologist of New South Wales, was inclined to consider crystalline rocks, such as those of Hill End, which contained distinct traces of pebbles as being highly metamorphosed conglomerates, and the comparative absence of metamorphism from the fine grained strata between these pebbly crystalline rocks he considered was due to selective metamorphism. These views he explained to me in the field when we examined the tin-bearing quartz-porphyries of New England, at Emmaville in 1883. Quartz-porphyries were observed by us at Rose Valley and elsewhere near Emmaville to contain water-worn pebbles of other rocks scattered throughout them. The line of strike of the pebbles cuts somewhat obliquely across the trend of the dyke or sill of quartz-porphry, and, on tracing it beyond the limits of the sill, we found that in either direction it passed into a typical conglomerate, the pebbles of which were set in a sedimentary base instead of a base of quartz-porphyry. It did not escape the eye of so keen an observer as Mr. Wilkinson, that selective metamorphism was incapable of explaining all these phenomena, and he directed my attention specially to further investigating this point when studying the geology of the Vegetable Creek district. I was, however, unable to obtain a satisfactory explanation until the year 1890, when a clue was given by the geological structure of the Junction Gold Mines near Mandurama, N. S. Wales, examined by me in that year. A note on the remarkable structure of the eruptive rocks at the above gold mine was contributed by me at the time to the Linnean Society of N. S. Wales.[1]

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[1] Proc. Linn. Soc. N. S. Wales, (Series 2nd) Vol. v., pp. 421 – 424.

The structure of the dioritic rocks of that neighbourhood described by me at that time as that of laccolites might, I now think, be more appropriately termed sill structure. A magnificent section illustrative of sill structure is exposed at "The Falls" above the Junction Mine, where a large dyke of diorite may be seen to have intersected the claystones almost vertically, and to have injected them, parallel or almost parallel to the planes of bedding, with sheets of rock from one-eighth of an inch to about twenty feet in thickness, and considerably over one hundred yards in length.

The following passage from my former paper describes the Mandurama sills:—"At first sight the precipitous hill side here appears to be composed of alternate beds of eruptive rock and altered sedimentary strata, at first mistaken by the author for a volcanic series of lavas alternating with fine tuffs. A closer examination, however, convinced Mr. Stonier and the author that these apparent beds were in reality intrusive laccolites, as evidenced by the slightly intrusive character of the junction line of their upper and under surfaces with the sedimentaries, their unbroken continuity with the diorite of the large dyke, the abundance of hornblende in them, and lastly the development of small light grey spots in the claystones near the point of contact, due probably to the formation of chiastolite. In places the laccolites have brought about a partial solution or fusion of the intruded sedimentaries, and where they pass into the so-called ore beds the author thinks they have intruded and replaced probably beds of limestone, absorbing into themselves the lime so as to form a type of rock of an ultra-basic character, for which perhaps the term *Manduramite* may be suggested."

The limestone at a neighbouring locality, on Mr. Rothery's Run, as I was informed by the late Professor Stephens, contains *Pentamerus*, and is therefore of Silurian or of Devonian age.

When the Australasian Association for the Advancement of Science met at Hobart in January, 1892, it was the opinion of Captain Hutton and some of the other members, including myself,

that the gigantic masses of gabbro which are so extensively developed along the estuary of the Derwent, as well as along the south-east coast, including Freycinet's Peninsula, are in reality sills rather than old lava flows, as was formerly contended by some. Their intrusive character had been ably argued for previously by Mr. T. Stephens, F.G.S. A subsequent examination has convinced me that the bulk of these gabbro rocks, such as those which form the fine headlands of Cape Pillar and Cape Raoul, as well as Mount Wellington, are sills. The intrusive mass at Mount Wellington might perhaps by some be termed a laccolite on account of its great size.

During a recent visit to Tamworth, in company with Mr. Donald Porter, I examined several sections near the town and at Moore Creek. The intricate way in which granite sills are there intercalated between the planes of bedding of the sedimentary rocks, if it does not baffle description, certainly baffles mapping. A zone of sills about five miles in width girdles the intrusive granite. The zone is composed of sedimentary rocks alternating with sills. The sedimentary rocks are of Devonian or possibly Silurian age, altered at their line of contact with the main boss of granite into garnet and chlorite rocks. These pass into an outer zone of chiastolitic rock. The latter is succeeded by fine grained claystones, converted by the sills into chert and jasper, and by the thin radiolarian limestones with the coralline limestones of Moore Creek, from one hundred to about 1,000 feet in thickness.

The sills in this outermost zone are from a fraction of an inch up to several yards in thickness, and alternate so regularly with the claystones and radiolarian cherts and limestones that it is difficult to believe that the eruptive rocks are not interbedded. The whole zone for several thousands of feet in thickness is half sill half sediment. A careful examination of the sills shows that they trespass slightly across the planes of bedding of the sedimentary rocks, and the latter along their planes of contact with the sills, both above and below, show evidence of contact metamor-

phism with development of white spots due probably to formations of chiastolitic minerals. The thin sills, from one-eighth of an inch up to about one foot, are greenish-grey in appearance, resembling quartz-diorites. The thicker sills, from over a foot up to several yards thick, have a more definite granitic aspect. In places where the sills have partly replaced fossiliferous crinoidal limestones, casts of the crinoid stems may be distinctly discerned in the granitic base of the sill. This obviously is the correct explanation of the apparent anomaly of the occurrence of fossils in the eruptive rocks at Hill End.

The occurence of waterworn pebbles in the sills at the above locality and also at Emmaville is, I now think, undoubtedly due to the same cause. The sills of fine grained granite and quartz-porphyry have, when intruding the conglomerates, dissolved and assimilated the base of the conglomerates, but have not been able to digest the less soluble pebbles. This is the origin of the zone of waterworn pebbles, at Rose Valley, Emmaville, striking obliquely across the large quartz-porphyry dyke, and passing in either direction, as soon as it leaves the dyke, into a typical sedimentary conglomerate. I would further suggest that the granitic bosses of New England etc. are laccolitic in shape rather than conical. If they were conical it is hard to understand why they should not have had strength enough to uplift Lower Silurian, Cambrian, and Pre-Cambrian rocks, which would have subsequently been exposed at the surface through denudation. As a matter of fact the oldest sedimentary rocks in contact with the New England granite appear to be Upper Silurian. On the laccolitic hypothesis the absence of rocks older than Upper Silurian around the granite can be explained. Immense volumes of granite may have been squeezed through comparatively small punctures in the Pre-Silurian crust, so that the lifting power of the granite on the rocks forming the sides of these relatively small well-holes would be far less than it would be around the periphery of a cone, the area of the base of which would considerably exceed the area near the summit of the cone exposed by denudation at the earth's surface.

On the PRESENCE of a TRUE MANNA on a "BLUE GRASS," *ANDROPOGON ANNULATUS*, Forsk.

By R. T. Baker, F.L.S., Assistant Curator and Botanist, Technological Museum, and Henry G. Smith, F.C.S., Chemist, Technological Museum.

[With Plates XXI–XXII.]

[*Read before the Royal Society of N. S. Wales, December 2, 1896.*]

The specimens, the subject of this paper, were obtained at Wild's Valley, Torren's Creek, viâ Townsville, Queensland, by Mr. J. R. Chisholm. They had, previous to our receiving them, been determined as *Spumaria alba*, Bull.—a fungus found on grass in this Colony and figured in Cook's Australian Fungi, Pl. 35, fig. 356, but as Mr. Chisholm was of opinion that they were galls, he asked if we would also examine them for him. Our first examination showed that they were manna and not a fungus, as we found that they consisted of large quantities of crystals, as well as some sugars.

A section of an individual mass showed the substance to be quite solid, with a cavity near its attachment to the grass, containing apparently excrement of some insect. As its general appearance very much resembled the well known Eucalyptus manna we were led to apply the usual tests for this substance, but with a result that large quantities of mannite were obtained, and so proving that it did not belong to that group of mannas.

In reply to a second letter on the subject, Mr. Chisholm writes: "There is one thing certain though, it has nothing to do with trees;[1] nothing whatever, existing on black soil plains, miles from timber of any kind. The flowering grass must be gathered in wet weather,[2] it is dry now. Sheep run about grubbing the white

[1] In reply to a letter asking if it had not dropped from a tree.

[2] In reply to a request for flowering specimens of the grass.

lumps of the grass, at least I say sheep, a sheep (Lincoln Ram) I feed on hay here, sorts over armfuls given him and picks out all the white lumps first, just like a child picking lollies out of hay. . . . Looking through the hay I cannot find a flower on the grass but will later; we call it "Blue Grass." A bushel of the manna could be gathered in an hour almost anywhere on the plains."

Later we received specimens of the grass; and when diagnosed these were found to be *Andropogon annulatus*, Forsk. This grass also occurs in Victoria, Northern Australia, and South Australia. It was described by Forskæl, Fl. Aegypt Arab. in 1775, and is widely spread over tropical Asia and Africa.

The description of this grass in B. Fl. Vol. VII., page 531 is as follows:—"Stems from a tufted base ascending to about two feet, the nodes glabrous or slightly bearded. Leaves narrow, usually glaucous. Spikes two or three, nearly sessile at the end of the peduncle without sheathing bracts, one and a-half to two inches long, the pedicels and base of the sessile spikelets much less ciliate than in the preceding species. Spikelets about two lines long. Outer glume of the sessile one membranous, prominently many-nerved, obtuse or three-toothed, ciliate on the margin and with a few long hairs on the back at the top; second glume thin, the midrib alone prominent, third very thin and hyaline; awn or terminal glume one third to three-fourths inch long, without any hyaline dilatation at the base. Pedicellate spikelet nearly similar but awnless, and with a male flower or reduced to empty glumes."

There are several other "Blue Grasses" occurring in the various colonies, such as the allied species *A. sericeus*, R.Br., and *A. affinis* R.Br., but we can find no record of any such substance as we are describing, as having been found on these, or for the matter of that, on any grass either in this continent or any part of the world.

The manna occurs in the form of nodules at the nodes of the stems, where its earliest stage of formation is marked by a slight

swelling of the stem and base of the leaves which afterwards split or divide longitudinally as the substance increases in dimensions. It eventually enlarges to the size of a marble or the top of a man's thumb. It is mostly white in colour and in general appearance resembles the corn-pop lollies of American confectionery, or the well known Eucalyptus manna. It is sweetish to the taste, is not moist, breaks down easily into fragments, and has a slight greasy feel. The surface is irregular, rugose, and granular.

A vertical or horizontal section gives a kidney-shaped surface, showing a cavity opening from the stem and filled with the excrement of a microlepidopterous insect—(according to Mr. W. W. Froggatt, Government Entomologist, to whom it was submitted for an opinion). The substance is quite white throughout, and in section shows radiating lines to the outer surface.

Microscopical Examination of the Manna.—When the powdered manna is placed upon a slide (better under a cover glass) and examined with the microscope, minute crystals are seen to be present in large quantities. With a quarter inch objective these are seen to be principally small prismatic crystals. They are too minute for the form to be determined, but under crossed nicols they polarize in faint colours of a light grey to dull yellow, and extinguish parallel to the principal axis. It is to be supposed, therefore, that they are crystals belonging to the rhombic system. They are naturally crystallised mannite. It is perhaps worthy of note, that naturally crystallised mannite polarises faintly in colours, while the crystals formed artificially from the same material, do not polarise in colours, with the exception of light grey, although they change from light to dark on being revolved between crossed nicols, the greatest darkness being when the prisms are parallel to the crossed webs. This was found to be the case also in the natural crystals of mannite from the manna of the sandalwood *Myoporum platycarpum*.[1]

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[1] Report on the vegetable exudations collected by the Elder Exploring Expedition.—Proc. R.S., S.A., 1892.

When carefully crystallised from water the crystals obtained are larger and better defined than when obtained from alcohol, being in rhombic prisms. Besides the crystals of mannite there is seen to be present minute organisms of a beaded structure, and requiring high powers to bring them out.

These spherical or egg-shaped bodies have no action on polarized light, but have a dark outer rim and a light nucleus within. They were not coloured blue by iodine.[1] These bodies resist the action of water at 100° C. Their appearance is illustrated in *Plate* 22, fig. 2.

By careful determination of these organisms, using a high power objective, it was seen that when placed in a dilute aqueous solution of cane sugar under a cover glass, that they bore a striking resemblance to the ferments allied to the yeast plant. They continued to slowly multiply by increasing from the centre. The original cell expanded and opened out, the minute fresh cells passing into a separate existence.

It appears remarkable that this ferment should exist in such a large quantity in this manna, and we have much pleasure in bringing it under the notice of the members of this Society. We consider that it may, perhaps, in some way, be responsible for the presence of the mannite found in the manna,[2] but at present we are not in a position to say definitely. Meanwhile we bring it under the notice of bacteriologists and biologists generally, so that investigations may be made respecting it. We suggest that perhaps it may be new to science, and its investigation may therefore be of some importance. From our short investigation we think that this ferment or fungus belongs to the Saccharomyces.

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[1] It may be as well to mention here that the manna does not contain starch in any degree. Several attempts were made to determine, if possible, the presence of this substance, but in no instance could it be detected, so that starch is not present in the manna.

[2] Mannite may be produced in considerable quantities by the fermentation of cane sugar.—Journ. Chem. Soc., XXXVIII., p. 100, and several other references.

It might, perhaps, be more accurately described as masses of oval or spherical cells, each cell consisting of a membrane and contents, which at first appear as a single body enclosed in the rather thick wall of the cell. This body eventually divides into two, three, or four vacuoles. *Plate* 22, fig. 3.

If placed in a weak solution of cane sugar, the cells multiply by gemmation a small body appearing at one side of the cell and growing till it becomes the size of the mother cell from which it is eventually constricted. Other cells are again produced from these till aggregations of numerous cells are formed, which are arranged in the form of a chain when production proceeds in a linear manner. These cylindrical cells have thick walls with a nucleated protoplasm. After an interval of several days the cells at the free ends of these chains appear to coalesce and form a club-shaped body, which in turn becomes greenish and opaque; the interior walls of the cells disappearing and the outer walls burst ejecting numerous minute spherical bodies or sporules. *Plate* 22, figs. 4 – 7.

To determine whether these organisms had the power to decompose cane sugar, four solutions were prepared as follows, sufficient cane-sugar being dissolved in water for the whole. They were each placed in a graduated tube over mercury.

No. 1, a portion of the organisms was added to a solution of pure cane sugar. In this experiment there was only added enough of the organisms to cause the liquid to be turbid. From the first to the ninth day the solution remained turbid and the organisms appeared to increase somewhat. On the ninth day one or two bubbles of gas made their appearance, the decomposition slowly proceeding until the twenty-eighth day, when 5·4 cubic centimetres of gas had been obtained.

To the 11th day ·6 cc. was obtained.

,,	12	,,	·5	,,	,,
,,	14	,,	·2	,,	,,
,,	15	,,	·5	,,	,,
,,	16	,,	·2	,,	,,

To the 17th day ·4 cc. was obtained.

,,	19	,,	·1	,,	,,
,,	20	,,	·2	,,	,,
,,	21	,,	·2	,,	,,
,,	22	,,	·2	,,	,,
,,	23	,,	·2	,,	,,
,,	24	,,	·4	,,	,,
,,	25	,,	·3	,,	,,
,,	26	,,	·4	,,	,,
,,	27	,,	·6	,,	,,
,,	28	,,	·4	,,	,,

These readings were all taken early each morning. On the completion of the decomposition, the gas was absorbed to a large extent by potash solution, indicating CO_2, but unfortunately owing to an accident the experiment could not be completed. The liquid, however, when distilled gave indications for alcohol. The products are thus the same as when decomposed by ordinary yeast. This experiment will be repeated on larger quantities of material and the products of decomposition determined quantitatively.

No. 2, a very small quantity of a solution of phosphoric acid, made alkaline with ammonia, was added to a portion of the same sugar solution as No. 1. Although the sugar solution remained turbid, yet, the organisms did not multiply to any extent, and there was no decomposition of the sugar with evolution of gas during three weeks.

No. 3, a minute portion of nitrate of potassium was added to the solution prepared as in No. 2. The solution soon became ropy and after a few days had become quite clear. No decomposition of the sugar took place.

No. 4, a portion of the cane sugar was boiled with hydrochloric acid, neutralised, made acid with tartaric acid, and the same quantity of the organisms added, no decomposition took place during three weeks.

Chemical Investigation.

Preliminary Examination.—The manna when dissolved in water has a sweet taste. It has slight reducing properties, giving a distinct reaction when heated with Fehling's solution, thus showing the presence of a reducing sugar. When a portion was boiled in dilute acid, the amount of copper reduced was apparently but little increased, indicating that other sugars were present, but in small quantity. It was thus seen that the sweetness of the manna must be derived from some other substance than sugar, and further tests discovered a crystallised body, of sweet taste, present in large quantities, and as seen below this substance is mannite. Besides the mannite and sugars, the manna contains a small quantity of gum, but no resin. Starch is also absent. An aqueous solution is acid to test paper. The identity of this acid was not determined, as the material at our disposal was not sufficient for that purpose, being used in other portions of the inquiry.

Moisture and Ash.—The amount of moisture in the powdered manna was found to be 7·19 per cent. It was heated in the air-bath at about 100° C. until constant. This dried material was then incinerated, and the ash found to equal 2·39 per cent., a portion of which was dirt. The inorganic constituents present were chlorine, sulphuric, phosphoric, and a trace of nitric acids, also carbonic acid from the decomposition of the organic matter. The bases being alumina, iron, lime, magnesia and the alkalis. As the material at our disposal was required for the organic work, a thorough quantitative analysis of the constituents of the ash was not made, but it appears to be derived from the grass debris, and the substances insoluble in water, together with some foreign admixture.

Estimation of the Glucose and other Sugars.—Two grams of the manna were dissolved in water and made up to 200 cc. It was found that it required 117 cc. of the solution to reduce 5 cc. of Fehling's copper solution, 5 cc. = ·025 gram glucose. The manna therefore contains 2·15 per cent. of a glucose.

To determine the amount of other sugars present, if any, two grams of the same manna were taken, dissolved in water, a small quantity of dilute hydrochloric acid added, and then boiled for half an hour. The solution was then cooled, made neutral, and brought up to 200 cc. It required 73 cc. of this solution to reduce 5 cc. of Fehling's copper solution, or equal to 3·425 per cent. of total sugars. As the glucose present equals 2·15 per cent., the manna contains, therefore, 1·275 per cent. of a sugar or sugars other than glucose.

Determination of the Mannite.—The mannite for this purpose was obtained from the manna by the following method, whereby it is obtained fairly pure at the first crystallisation. A quantity of the powdered manna was boiled in a small quantity of rectified spirit. The alcohol when removed was dark coloured, and deposited some mannite on cooling; it appeared to contain the greater portion of the sugars. This portion was discarded. The manna was then boiled in several portions of rectified spirit, these were mixed together; on cooling a good quantity of mannite crystallised out in needles and plates. It was fairly white in colour and the alcohol was but slightly coloured. The crystals were removed, placed on a porous slab to drain, recrystallised from water, and again drained on the slab. The mannite is thus readily obtained almost pure. For the more delicate reactions the mannite was again recrystallised from alcohol and water. The use of animal charcoal was not needed.

The tests whereby these crystals were determined as mannite are as follows:—

1. The crystals are rhombic prisms.

2. They were very soluble in water; slightly soluble in cold alcohol, readily on boiling; and were insoluble in ether.

3. When dissolved in water the solution had no action on light in the polarimeter, being optically inactive.

4. When the crystals were dissolved in water and treated with fresh yeast, no fermentation took place during twenty-four hours.

5. When boiled with Fehling's solution no reduction took place,

nor was the copper reduced after a solution had been boiled in dilute acid, so that the substance does not undergo hydrolysis by this method.

6. The crystals melted at 165° - 166° C. in glycerol in tube closed at end.

7. The crystals dissolved in concentrated sulphuric acid without darkening.

8. When boiled with potash an aqueous solution is not darkened.

9. With ammonio-sulphate of copper, a blue precipitate was obtained, soluble in ammonia, and this solution was not altered on boiling.

10. With ammonical lead acetate a white precipitate was obtained.

11. When an aqueous solution was added to either lime or baryta water, and alcohol added, precipitates were obtained.

12. The purified substance was sweet to the taste.

13. When treated with strong nitric acid, and heated until the evolution of gas ceased, the oxidation products formed gave the reactions for saccharic and oxalic acids, no mucic acid was detected.

14. When the purified crystals were heated to 105° C. for half an hour, no change in weight took place, nor was there any alteration when heated to 116° C., so that the crystals are anhydrous at that temperature.

15. Combustion was made of perfectly purified material with the following result :—

·2538 gram gave ·3658 gram CO_2
and ·1766 „ H_2O

which is equal to 39·31 per cent. carbon
7·72 „ hydrogen
52·97 „ oxygen.

From which we may deduce the formula $C_6H_{14}O_6$ or that of mannite.

Theory requires for this formula—

Carbon	...	39·56 per cent.
Hydrogen	...	7·69 „
Oxygen	...	52·75 „

From the results of the above tests, it is certain that the crystallised substance from this grass manna is mannite.

Quantitative determinations of the Mannite.—A portion of the manna was dissolved in water, alcohol and acetate of lead added, a good precipitate forms, which easily separates, the filtrate being quite clear. From the filtrate the lead was removed by sulphuretted hydrogen, the solution evaporated to dryness and boiled out with 90% alcohol, filtered, evaporated to dryness, and weighed. In this way 60·5% of mannite was obtained. As the greater portion of the sugars were by this method probably present, it was again dissolved in boiling alcohol, evaporated down, precipitated by ether, filtered, dried, and weighed. By this method the percentage was 58·98 of mannite. As the decomposition of the sugars by fermentation with yeast is slow, and perhaps not satisfactory, (see determination of the fermentation of the manna below), the method of determining the mannite gravimetrically by decomposing the sugars by yeast was not undertaken. As the total amount of the sugars present is only just above 3%, there could not be less than 57% of mannite present in the manna taken for analysis. As it is, perhaps, hardly possible to determine with accuracy the gravimetric value of mannite in mixed material like the present, we consider that we are justified in stating the approximate amount of mannite in this grass manna as 58 per cent.

The gum was determined in the usual way.

The substances insoluble in water were found to equal 27·58 per cent. and consisted partly of debris, broken grass, and substances of that character, partly of a small portion of carbohydrates allied to the gums, but largely consisting of a smooth light dirty-drab coloured mucilaginous substance that prevented the ready filtration of the material and which was practically an insoluble ferment. It has been described earlier in the paper.

From the above results we have the following analysis:—

Substances soluble in water						= 72·42	per cent.
Substances insoluble in water						= 27·58	,,
Moisture	...	...	...	...	...	= 7·190	per cent.
Mannite	...	...	...	...	...	= 58·000	,,
Glucose	...	...	...	...	...	= 2·150	,,
Other sugars	...	...	...	...	...	= 1·275	,,
Gum soluble in water			...	...	...	= 2·400	,,
Soluble in alkali ? gum			...	...	...	= 1·780	,,
Soluble in acid ? gum	...		...	...	...	= ·690	,,
Ash	...	...	...	...	...	= 2·390	,,
Debris, dirt, and the fermentation fungus						= 22·720	,,
Nitrogenous bodies etc. undetermined, and loss						= 1·405	,,
						100·000	

We may therefore consider that the chief product of this grass manna is mannite.

Fermentation of the Manna with Yeast.—0·9 gram of the manna was dissolved in water, mixed with a little fresh yeast, and placed in a graduated tube over mercury.[1]

The readings were taken the first thing in the morning in every case, the temperature then being about the same.

The first twenty-four hours			gave	1·7	cc. of gas.
,,	second	,,	,,	2·0	,,
,,	third	,,	,,	2·2	,,
,,	fourth	,,	,,	1·6	,,
,,	fifth	,,	,,	9·7	,,
,,	sixth	,,	,,	3·7	,,
,,	seventh	,,	,,	5·7	,,
,,	eighth	,,	,,	1·3	,,

[1] For comparison a portion of cane-sugar was inverted, neutralised, made slightly acid with tartaric acid, yeast added in the same proportion, and placed by the side of the manna determination. Fermentation rapidly set in, and the whole was destroyed in twenty-four hours, no further action taking place after that time.

The	ninth	twenty-four hours	gave	0·3	,,
,,	tenth	,,	,,	2·8	,,
,,	eleventh	,,	,,	0·0	,,
,,	twelfth	,,	,,	1·0	,,

It will be observed that during the last few days the rate of decomposition was very irregular. The temperature during each day was from 80° to 85° F. when highest. No further gas was obtained after the twelfth day, so that the product was 32 cc. of gas. After the first few days there had been obtained more than sufficient gas to account for the whole of the sugar found to be present in the manna. It is evident, therefore, that the decomposition of other substances must have taken place. It is generally accepted that mannite itself does not ferment with ordinary yeast. It is thus difficult to understand what other substances can be present in the manna to be decomposed by yeast, with the formation of CO_2, if the mannite is not acted upon. The reaction may be probably due to the presence of the organisms found in the manna, acting with the yeast introduced. The organisms in the manna have the power of decomposing cane sugar, under certain conditions, with the evolution of gas. The subject is extremely interesting and worthy of more research, and as we are expecting to receive shortly much more material, the matter will be further investigated. The CO_2 calculated theoretically from the volume obtained, is equivalent to 14·33 per cent. of sugar considered as glucose, which is more than four times as much as was found to be present in the manna.

This is the second record of the occurrence of a true manna in Australia. The first being described by J. H. Maiden, F.L.S.,[1] in an exudation from *Myoporum platycarpum*, R.Br.

Our specimen is quite distinct from either the Eucalyptus manna, or lerp, as these substances contain sugars and not mannite. This latter is found in the dried juice which exudes from the Manna Ash *(Fraxinus ornus)*. Mannite occurs in many other

[1] *Op. cit.*

plants, *e.g.*, the roots of Aconite, *Aconitum napellus*, Linn.; Celery, *Apium graveolens;* Mew, *Meum athamanticum;* Hemlock-water-drop, *Œnanthe crocata; Polypodium vulgare; Scorzonera hispanica* and *Triticum repens;* and in the root-bark of *Tunica granatum.* Mannite also occurs in the bark of wild cinnamon, *Canellia alba*, Murr. (8%), and of Ash *Fraxinus excelsor;* in the leaves and young twigs of *Syringa vulgaris;* in the leaves of *Ligustrum vulgare* and of *Cocos nucifera*, Linn., and in the fruit of *Laurus persea*, and of *Cactus opuntia.* Mannite also occurs in *Laminaria saccharina;* in olives, and in several fungi, *e.g.*, *Lactarius vellereus; L. turpis; L. pyrogalus* and *L. pallidus.* *Agaricus integer* contains 20% of its dry substance. It also occurs in the cambium layer of coniferæ (Payen, A. 12,60; Meyer a. Reiche.)

The official manna is obtained from the dried juice which exudes from the Manna Ash (*Fraxinus ornus*, Linn.), but substances that go by the name of manna have been obtained from the following, and have been used at various times for food or medicine:—*Alhagi camelorum*, Fisch., *A. maurorum*, Desv.; *Atraphaxis spinosa*, Linn.; *Calotropis gigantea*, R.Br.; *Cedrus Libani*, Barr.; *Cotoneaster acutifolia*, Linn., according to Aitchison; *C. nummularia*, F. et M.; *Musa superba*, Roxb.; *Palmæ*, various species; *Pinus excelsa*, Wall.; *Quercus incana*, Roxb.; *Rhododendron arboreum*, Sm.; *Tamarix* sp.; *Salix* sp., according to Stewart; *Salsola fœtida*, Del., according to Stewart and Aitchison; *Eucalyptus* spp.

Glyceria fluitans, R.Br., is known in many parts of the world as "Manna Grass," not that manna has been found on it, but that the seeds are sweet and used for food. A lichen, *Leonora esculenta*, is found in portions of Arabia and there used for food, under the name of manna.

Medical Properties and Uses of Manna.—Manna is a mild laxative. It is especially suitable for children and delicate persons, and also as an adjunct to more active aperients in order to assist their action, and to disguise their disagreeable taste. Manna is now far less used in England than formerly.

Mannite possesses similar laxative properties to that of manna, and is frequently employed on that account in Italy.[1]

We advance no theory as to the origin of this manna, as that lies in the province of the entomologist, but Mr. W. W. Froggatt is of the opinion that it is due to some action of a homopterous insect on the stem of the grass.

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Explanation of Plates.

PLATE XXI.

Sketch of the "Blue Grass," *Andropogon annulatus*, Forsk.

Figs. 1, 2 and 3—Stages showing the development of the manna on the stems. (Reduced to $\frac{5}{9}$ size)

Fig. 4—Section of 3, showing cavity containing excrement of insect. (Reduced to $\frac{5}{9}$ size)

PLATE XXII.

Fig. 1—Manna under $\frac{1}{4}$ objective.
Fig. 2—Mannite crystals removed from the substance leaving sporules.
Fig. 3—Cells showing mode of multiplying. × 450 diam.
Fig. 4—Showing production of cells on a chain or linear manner. × 450 diam.
Fig. 5—Later growth of No. 4.
Fig. 6—Club shaped body or aggregation of cells with sporules escaping. × 450.
Fig. 7—Sporules in "strings of beads" found with No. 6. × 450 diam.

Nos. 3, 4, 5, 6 and 7, all in a solution of cane sugar.

The RIGOROUS THEORY of the DETERMINATION of the MERIDIAN LINE by ALTAZIMUTH SOLAR OBSERVATIONS.

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1. *Introduction.*—Although it cannot be expected that solar observations for the determination of the meridian line, will yield results equal in precision to those which may be derived from stellar observations—chiefly on account of the greater unsteadiness of the atmosphere during the day, and of the larger uncertainty in the magnitude of the refraction—yet their convenience often

indicates that they are to be preferred under certain circumstances. In order to attain to the ultimate degree of precision possible with this method, and to form a just estimate of its value, it is necessary to eliminate at least every source of systematic error, and to have regard to conditions of accuracy generally. These last, vary with changes of the sun's declination and with its altitude, and are moreover different in different latitudes. Is is proposed therefore to develope rigorously the theory of the subject, because the rigorous theory will not be without utility in attempts to perfect the method.

2. *Instrumental Theory.*—An observation for the determination of the meridian line, consists essentially of a measurement of the direction or *azimuth*, and of the *altitude*, or of its complement the *zenith distance*, of the celestial object selected for the purpose. The result is consequently affected both by instrumental and by astronomical conditions. The former involve an investigation of the particular instrument used, and the application of the general theory of corrections for the errors of instruments. The principles of the investigation of the first element have been elsewhere discussed,[1] and are outside the scope of this paper.

The only corrections to be applied to observations besides that for the index or constant error of the zero of the vertical circle, are those for the collimation and level errors.[2] If c denote the angle between the sight line of the telescope and the plane at right angles to its rotation axis—considered as positive towards

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[1] By Bessel, C. A. F. Peters, Hansen and others. The theory of the errors of instruments is admirably treated in Chauvenet's Spherical and Practical Astronomy, Vol. II., Philadelphia 1863. See also Clarke's Geodesy, London 1880. The Surveyor, Sydney, Vol. I., Nos. 2, 4, 10, 1888–1889. On the rigorous examination and use of transit theodolites by G. H. Knibbs. Also the theory of the repetition of angular measures with theodolites.—Journ. Royal Society, N.S.W., Vol. XXIV., pp. 87–106, 1890, by the same author.

[2] Errors of eccentricity are eliminated by taking the mean of the readings of the microscopes, dividing the graduated circles into equal parts. Corrections to particular graduations would be also applied if an investigation had revealed their existence.

the right, looking through the telescope, inasmuch as the circles are graduated "clockwise"—the collimation *correction* μ to the horizontal circle is, for the altitude h,

$$\mu = c\ (\sec h - 1) \ldots\ldots\ldots (1)$$

μ and c being in the same units, seconds say. If, looking through the telescope, the *left hand* side of its pivots be raised so that the rotation axis is inclined i with the horizontal, the similar *correction* λ for the same altitude is,—

$$\lambda = i \tan h \ldots\ldots\ldots (2)$$

λ and i being in the same units.

Since these corrections are always very small, they may be applied independently, without introducing sensible error except-ing near the zenith, a case with which we are not here concerned, since such points are unsuitable for azimuth determinations. The effect of applying the corrections is obviously to reduce the recorded direction to that which would be given by a perfectly adjusted instrument. In regard to the recorded altitude, it need only be remarked that if the alidade level alter from the position of adjustment, the reading must be corrected by the whole amount of the level movement. In order to eliminate the corrections (1) and (2) from the results of observations, it is usual where possible to reverse the instrument for each pair, so that the constants, having then opposite signs, will involve the disappearance of the *nearly* equal corrections from the mean of the observations. It will be sufficient to observe that since c and i are always very small, slight changes of altitude do not vitiate this proceeding, by importing into the result errors of sensible magnitude, in conse-quence of regarding the corrections as *exactly* equal. This will be seen by differentiating (1) and (2) for we shall then have for the differential corrections at any altitude, for a small change thereof

$$d\mu = c \sec h \tan h\ dh \ldots\ldots\ldots (3)$$

$$d\lambda = i \sec^2 h\ dh \ldots\ldots\ldots\ldots (4)$$

in which dh will of course be expressed in radians or 'circular measure,' the other units being as before. These differential corrections and their differentials again, both increase when the

altitude increases. In order to get a definite idea of their magnitude, we may suppose h to amount to 45° as a maximum in the class of observations to which we are referring, and dh to be 1°; then if c and i were even as large as one minute of arc, the corrections would amount to only 1·″5 and 2·″1 respectively. It is evident therefore that the second differences of the corrections are extremely small, and consequently that the error of using the mean altitude, as the argument for the computation of a correction for the collimation or level constant, cannot lead to sensible error so far as least as the defect of instrumental adjustment is concerned. It may easily be shewn that the respective corrections ϵ_m and ϵ_l on the correction applied to the mean altitude, the total difference being the altitudes being 2β, are

$$\epsilon_m = \tfrac{1}{2} c \tan^2 \beta \sec h (1 + 2 \tan^2 h) + \text{etc}.....(5)$$

$$\epsilon_l = i \tan^2 \beta \tan h (1 + \tan^2 h) + \text{etc}.....(6)$$

which give for $\beta = 1°$, c and $i = 60″$, and $h = 45°$ the values, 0·″039 and 0·″036 respectively, and even for $h = 60°$, only 0·″128 and 0·″127. With large theodolites and altazimuth instruments, the errors ought not to amount to even one fourth of this. Again, the interval of time between observations differing 2° in altitude can never be less than 8 minutes, and this is more than sufficient for the reading and recording of an observation and the preparation for the next one. With half the interval the corrections are clearly but one-fourth of the amount. The above dictum is therefore justified, and with this the discussion of the instrumental theory may be dismissed.

3. *Almucantars and great circles tangent thereto.*—Turning to the astronomical conditions of the problem, it will be necessary in the course of their examination to determine the magnitude and law of increase of the distance between small and great circles, as for example between an almucantar or parallel of altitude, and a great circle of the celestial sphere tangent thereto, as we proceed along the latter from the tangent point. By developing the tangent cone, whose line of contact with the sphere is the almucantar of the zenith distance z, and employing the binomial

expansion for expressing the distance between this curve and the plane development of the great circle, it is at once evident that the distance sought is

$$dz = \tfrac{1}{2} S^2 \cot z - \tfrac{1}{8} S^4 \cot^3 z + \text{etc.}\ldots\ldots\ldots(7)$$

in which S is measured on the great circle. If dz be required in seconds, S should be expressed in seconds, and the terms S^2 and S^4 etc. multiplied respectively by arc $1''$, arc^3 $1''$ etc. The second term, even for a zenith distance of only $5°$, amounts only to $0.''018$ for the semidiameter of the sun. For $5°$ altitude the first term similarly amounts only to $0.''19$.

4. *Error of the mean of true altitudes* as a datum for the computation of azimuth or time; *zero declination.* In § 2 it was remarked that the mean of the observed altitudes and of the directions of a celestial object, as given by the instrument in reversed positions was often employed as a basis for computations of azimuth, and it was also shewn in that section that the differentials of the corrections for the instrumental constants did not sensibly affect the result. The error of using the mean altitude requires consideration, however, also from the standpoint of spherical geometry. We shall suppose that the observed altitudes are independently corrected for refraction, and that the mean is that of the corrected altitudes.

In Fig. 1 let Z H denote a vertical circle crossing a star's path, which may be represented by R S T, R Q T, or R S′T according as the polar distance P S, P Q or P S′ is less than, equal to, or greater than $90°$; so that for any one of these three cases, R Q T will denote a great circle on the celestial sphere. Then if these arcs be bisected by the points S Q S′, the great circle passing through them will also pass through the celestial pole P. From R and T draw the great circles R r and T t cutting Z H at right angles, and draw also the almucantars R r′ and T t′, so that r′ and t′ are points on the vertical Z H of the same altitude as R and T. Let us further suppose the difference of the altitudes *corrected for refraction* of these points to be 2β, and the angle of intersection between the great circle and the vertical, viz. R Q Z to be I.

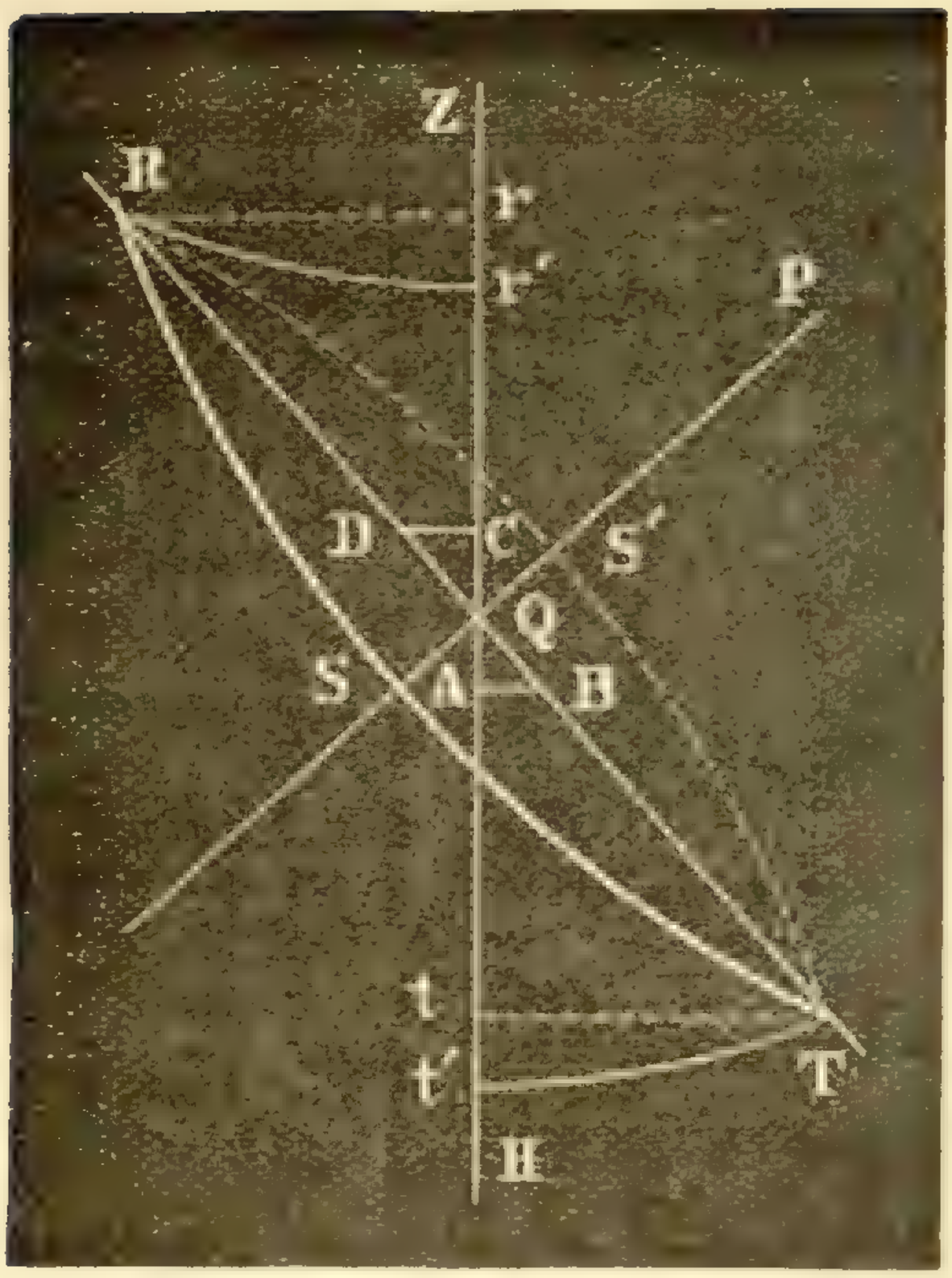

Fig. 1.

Then, ζ denoting the mean of the corrected zenith distances of R and T, we shall have by (7), β being supposed small, so that no sensible differences exist between the arc, sine, or tangent of this angle

$$\mathrm{r\,r'} = \tfrac{1}{2}\beta^2 \tan^2 I \cot(\zeta - \beta) \ldots\ldots\ldots\ldots\ldots\ldots (a)$$

$$\mathrm{t\,t'} = \tfrac{1}{2}\beta^2 \tan^2 I \cot(\zeta + \beta) \ldots\ldots\ldots\ldots\ldots\ldots (b)$$

with abundant precision, the term in β^4 being negligible, for even if R and T differ in altitude 2°, this fourth power will be only about $\frac{1}{11000000}$. Taking the mean of these quantities therefore, we have for the distance A Q, A being the point whose zenith distance is ζ, *i.e.* the mean of the zenith distances of R and T,

$$\mathrm{A\,Q} = \tfrac{1}{2}\beta^2 \tan^2 I \cot\zeta + \mathrm{etc} \ldots\ldots\ldots\ldots\ldots\ldots (c)$$

The omitted term in β^4, for $\beta = 1°$, ζ and $I = 45°$ will involve an error of only $\frac{1}{1840}$: the higher powers are quite insensible. The simplest method of deducing an exact result is to correct the mean of the zenith distances; which uncorrected would, of course, give the azimuth or hour angle of the point B, the altitude of which is equal to that of A. Hence in *computations of time*, the quantity (*c*) with the negative sign should be applied to the mean of the

zenith distances; for it is evident from the figure that at the mean of the times the star would have been at Q. This point, however, does not represent the mean of the *directions* of R and T, since the former is 2β nearer the zenith. Since $R\,r = T\,t = \beta \tan I$, the difference of azimuth between D—the mean of the azimuths of R and T—and Q, viz. the angle Q Z D, not drawn in the figure, is expressed by the formula

$$\text{Angle Q Z D} = \tfrac{1}{2}\beta \tan I\,[\text{cosec}\,(\zeta - \beta) - \text{cosec}\,(\zeta + \beta)] \ldots\ldots (d)$$

By expanding the terms in the brackets, multiplying by $\sin\zeta$, and rejecting the higher powers of β as inappreciable, the distance C D from the vertical through Q, of a point D, so taken as to be the mean of the azimuths of R and T is obtained

$$C\,D = \beta^2 \tan I \cot\zeta \ldots\ldots\ldots\ldots (e)$$

Multiplying by $\cot I$, we get the difference of altitude between this point and Q, viz.

$$C\,Q = \beta^2 \cot\zeta \ldots\ldots\ldots\ldots\ldots\ldots (f)$$

Remembering that if α denote the change of azimuth for the change of altitude β

$$\tan I = \frac{\alpha}{\beta} \sin\zeta, \text{ very nearly} \ldots\ldots (g)$$

since α and β are supposed small, *i.e.* always less than say about 1°, the *corrections* to the mean zenith distance, for a star or the sun *when the declination is zero*, are, for the computation of azimuth and of time, respectively

$$\epsilon_o = -(A\,Q + Q\,C) = -(\tfrac{1}{4}\alpha^2 \sin 2\zeta + \beta^2 \cot\zeta) \ldots\ldots\ldots (8)$$

$$\eta_o = -A\,Q = -\tfrac{1}{4}\alpha^2 \sin 2\zeta \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

By means of the approximate equation

$$\beta^2 + \alpha^2 \sin^2\zeta = t^2 \sin^2 p \ldots\ldots (h)$$

p denoting polar distance—in this case 90°—the sine therefore being unity, (8) and (9) may be reëxpressed by substituting the semi-interval of time for the semi-interval of azimuth: thus

$$\epsilon_o = -\tfrac{1}{2}\cot\zeta\,(t^2 \sin^2 p + \beta^2) \ldots\ldots\ldots\ldots (8a)$$

$$\eta_o = -\tfrac{1}{2}\cot\zeta\,(t^2 \sin^2 p - \beta^2) \ldots\ldots\ldots\ldots (9a)$$

In these four equations, if the corrections are required in seconds, α, β, and t should be expressed in seconds, and the result multiplied by arc 1″. The time t must also be expressed in arc, or the

seconds of time multiplied by 15, before being squared. The latter equations are the more convenient, and the corrections are readily tabulated. In the following example, which will illustrate the precision of the correction method, the latitude ϕ is assumed to be 35°, the polar distance is 90°, and the zenith distances 44° and 46°. From these data we find, $a = 1^\circ\ 57'\ 53{\cdot}95''$, $\beta = 1^\circ$, $t = 1^\circ\ 42'\ 41{\cdot}70''$. By calculating in the ordinary manner and also from the "corrected" mean altitude[1] we get respectively, A denoting azimuth, and T hour angle,

		°	′	″		°	′	″		°	′	″
Means	A =	134	30	39·71	T	30	17	28·70	I	54	16	9
By (8) and (9) =		134	30	39·73		30	17	28·77	By (g)	54	16	25

These differences are very small, notwithstanding that the case is an exceptional one, the interval between the observations being no less than $13^m\ 41{\cdot}56^s$.

5. *Error of the mean of true altitudes* as a datum for the computation of azimuth or time: *any declination.* In general it is necessary to apply the corrections however, for cases were the star or sun moves in a small instead of a great circle, *i.e.* when its polar distance is other than 90°. As previously remarked, the line R Q T in Fig. 1 will, in the general case, represent a great circle drawn through the positions occupied by the star at the moments of observation. The vertical Z H is drawn, not through the middle point of the star's path as in the preceding section, but through the middle point Q of this great circle. It is evident from considerations of symmetry that the declination circle passing through this point will intersect the star's path at its middle point S or S′, hence to the formulæ already obtained it is necessary only to add terms depending on the distance of this middle point from Q.

By Lagrange's development, rejecting as negligible the powers of t higher than the second, since they are of the same order as the similar terms rejected throughout, we have

[1] The corrections to the zenith distances are by (8) $2'\ 3{\cdot}''48$: by (9) $1'\ 0{\cdot}''64$.

Q S or Q S′ $= \tan^2 \frac{1}{2} t \sin 2p = \frac{1}{4} t^2 \sin 2p$, very nearly.....(*i*)
the simpler form being also given at once, *mutatis mutandis*, by (7). This quantity is negative when the polar distance is greater than 90°, therefore the direction Q towards S must be regarded as positive. To the previous corrections to the zenith distances, therefore, we must add the difference of zenith distance between Q and S, which is[1]

Q s or Q s′ $= \frac{1}{4} t^2 \sin 2p \sin I = \frac{1}{4} \alpha t \sin \zeta \sin 2p$.....(*j*)
the last expression being deduced by the ratio Q T/T t = S Q/Q s, and containing only factors given by observation. By means of (*h*) the final formulæ for the general case may be expressed either in terms of β and α, or β and t. In this way, we may reëxpress (*j*) thus :—

$$\text{Q s or Q s}' = \tfrac{1}{2} \alpha \sin \zeta \cos p \sqrt{(\alpha^2 \sin^2 \zeta + \beta^2)}$$
$$= \tfrac{1}{2} t \cos p \sqrt{(t^2 \sin^2 p - \beta^2)} \quad (k)$$

and from these last expressions, and those previously deduced, obtain, by simple addition, the general values of the *corrections* sought, viz. ϵ for azimuth, η for time.

$$\epsilon = \eta - \beta^2 \cot \zeta \quad (10)$$

$$\eta = \tfrac{1}{2} \alpha \sin \zeta \left[\cos p \sqrt{(\alpha^2 \sin^2 \zeta + \beta^2)} - \alpha \cos \zeta\right] \quad (11)$$

Since $t \sin p$ is always greater than β, see Fig. 1, the similar expressions, in terms of t instead of α, may be written, using the auxiliary ω for brevity,

$$\omega = \tfrac{1}{2} t^2 \sin^2 p \left[\cot p \sqrt{\left(1 - \frac{\beta^2}{t^2} \operatorname{cosec}^2 p\right)} - \cot \zeta\right] \quad (12)$$

$$\epsilon = \omega - \tfrac{1}{2} \beta^2 \cot \zeta \quad (13)$$

$$\eta = \omega + \tfrac{1}{2} \beta^2 \cot \zeta \quad (14)$$

The term within the rectangular brackets in (12) is a factor in which the unit of β and t is indifferent : these quantities may therefore be expressed in either degrees, minutes or seconds ; the other factor, and the β terms in (13) and (14) are easily tabulated. As we are dealing with small quantities the computations may be readily made, and involve less expenditure of time than is involved in the calculation of two spherical triangles. Tables I. and II.

[1] Note that s and s′ are not shewn in Fig. 1. They would be the points determined by letting fall the perpendiculars S s and S′s′ on to Z H.

will facilitate the computations. It may be remarked that the bracketed factor in (12) is generally very small and consequently a very rough calculation of its value is all that is required.

TABLE I.—*Values of* $\frac{1}{2}\ t^2 \sin^2 p$.

Semi-interval of Time	Polar Distances. 10°	20°	30°	40°	50°	60°	70°	80°	90°
t	170	160	150	140	130	120	110	100	90
1 min.	0·1″	0·2″	0·5″	0·8″	1·2″	1·5″	1·7″	1·9″	2·0″
2	0·2	0·9	2·0	3·2	4·6	5·9	6·9	7·6	7·9
3	0·5	2·1	4·4	7·3	10·4	13·3	15·6	17·1	17·7
4	0·9	3·7	7·9	13·0	18·4	23·6	27·7	30·5	31·4
5	1·5	5·7	12·3	20·3	28·8	36·8	43·3	47·6	49·1
6	2·1	8·3	17·7	29·2	41·5	53·0	62·4	68·6	70·7
7	2·9	11·3	24·1	39·8	56·5	72·2	85·0	93·3	96·2
8	3·8	14·7	31·4	51·9	73·7	94·2	111·0	121·9	125·7

TABLE II.—*Values* of $\frac{1}{2}\ \beta^2 \cot \zeta$.

Semi-difference.	True Zenith Distances. 30°	35°	40°	45°	50°	55°	60°	70°	80°
β									
10′	1·5″	1·2″	1·0″	0·9″	0·7″	0·6″	0·5″	0·3″	0·2″
15	3·4	2·8	2·3	2·0	1·6	1·4	1·1	0·7	0·3
20	6·0	5·0	4·2	3·5	2·9	2·4	2·0	1·3	0·6
30	13·6	11·2	9·4	7·9	6·6	5·5	4·5	2·9	1·4
40	24·2	19·9	16·6	14·0	11·7	9·8	8·1	5·1	2·5
50	37·8	31·2	26·0	21·8	18·3	15·3	12·6	7·9	3·8
60	54·4	44·9	37·4	31·4	26·4	22·0	18·1	11·4	5·5
75	85·0	70·1	58·5	49·1	41·2	34·4	28·3	17·9	8·7
90	122·4	100·9	84·2	70·7	59·3	49·5	40·8	25·7	12·5

The application of the tables, by means of which the values of the corrections may be interpolated by inspection, does not require illustration, and it is only necessary to remember that a, β or t are *one-half* of the observed differences between the azimuths, of the zenith distances corrected for refraction, or of the times.

6. *Refraction Error of the mean of observed altitudes.*—In the case discussed in the preceding section, the error of employing the mean of the true altitudes of a star has been investigated. We

now propose to determine the further error involved, where instead of so doing, the mean of the observed altitudes, is corrected for refraction. Since the refraction increases more rapidly than the zenith distance it is evident that *the refraction for the mean of the observed zenith distances is less than the mean of the refractions* of those distances. The difference is very small near the zenith, but becomes very appreciable near the horizon. At 45° it is about 0·″01 for a difference of 1° in zenith distance between the mean and either observation and, as will presently be shewn, varies as the square of that difference. Let $z \pm b$ denote the zenith distances given by observation, so that z is the means of, and b the half difference between the two: let also r be the refraction corresponding to z, and r_1 and r_2 the refractions for the observed zenith distances. Then e being the correction to the refraction r, we have for the mean of the true zenith distances

$$z + \tfrac{1}{2}(r_1 + r_2) = z + r + e \ldots\ldots\ldots (l)$$

For small changes of zenith distance the refraction may be put in the form

$$r = k \tan z \ldots\ldots\ldots\ldots\ldots (m)$$

in which, since k varies very slowly with z excepting near the horizon it may be treated as constant. Hence substituting in this last expression, $z \mp b$ for z, we obtain for the value of the correction

$$e = r \tan^2 b \sec^2 z + \text{etc} \ldots\ldots\ldots\ldots (15) \text{ approx.}$$

the sign of which is always positive; in other words the mean of the true zenith distances, is greater than the zenith distance computed by applying the refraction correction to the mean of the observed zenith distances. The above formula, however, is only suitable above 20° altitude at which value its error is about 0·″02. Between $z = 70°$ to $z = 90°$, it is unsuitable, because the variation in k, not taken into account, is not negligible, and appreciable terms are also neglected. When very great accuracy is required nothing is gained for low altitudes by the application of the correction to the refraction for the mean altitude: it is more convenient to correct each independently. On the other hand the following table will permit of accurate interpolations of the error

at any zenith distance when moderate accuracy only is required, or when the differences of the corrections only have to be determined.

TABLE III.—*Correction of the Refraction of the Observed Mean Zenith Distance for a semidifference of 1°. Barom. 29·6 Therm. 48·75 Fahr.*

Appt. Zenith Distance	45°	50°	55°	60°	65°	70°	75°
Corr. to Refract. +	·03″	·05″	·08″	·12″	·21″	·39″	·90″
Appt. Zenith Distance	77½°	80°	81°	82°	83°	84°	85°
Corr. to Refract. +	1·50″	2·71″	3·63″	4·86″	6·78″	9·77″	14·65″

The correction for any other semidifference of apparent zenith distance may be approximately found by multiplying the tabular value by the *square* of the semidifference expressed in degrees and decimals of a degree. For any other pressure B, and air temperature τ, the tabular quantities should be multiplied by factors expressing the barometric and thermometric corrections to the tabular refractions. These factors[1] are

$$\frac{B}{29{\cdot}6} \cdot \frac{461{\cdot}75}{413+\tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots (n)$$

The corrections for the error, which it is necessary to apply to the azimuthal angle measured from the elevated pole, and to the hour angle measured from the meridian toward east or west will be respectively

$$e_a = -\, e\,\frac{a}{\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots (16)$$

$$e_t = +\, e_a \sin\zeta \sec\delta \quad \ldots\ldots\ldots\ldots (17)$$

as it is easy to see from (g) in § 4 : δ of course denotes declination.

7. *Diurnal Aberration.*—The orbital motion of the earth causes a displacement, called the annual aberration, of the position of the sun and stars ; which being independent of locality on the terrestrial surface, is taken cognisance of in the apparent right ascensions and declinations tabulated in ephemerides. The diurnal

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[1] The coefficient $461{\cdot}75/413+\tau$ approximately expresses the air temperature factor of Bessel's refractions. In its stead the factor T in Chamber's Mathematical Tables, p. 431, Edit 1885, may be used with advantage. For 0° Fahr. it is 1·106, for 100° Fahr. 0·909.

rotation however, also causes an aberration, which, on the contrary, is dependent on locality, and cannot therefore be thus generally treated. The effect of this daily rotation is to displace a star towards the east, the displacement being called the *diurnal aberration*. Its ratio to the annual aberration is obviously that of the rotational velocity of a terrestrial point to the velocity of the earth's centre. This rotational velocity varies as the product of the geocentric radius of the earth ρ', and the cosine of the geocentric latitude ϕ', that is as $\rho' \cos \phi'$. As the compression is less than $\frac{1}{2}\frac{1}{9}\frac{1}{3}$ and consequently the astronomical and geocentric latitudes differ never more than 11′ 44″, we may assume that the rotational velocity varies as the cosine of the astronomical latitude and this will never lead to sensible error, since the aberration itself is a very small quantity.[1] Assuming the orbit to be circular and its radius to be unity, the value of the earth's equatorial radius will be sin 8·″848; and as there are 366·256 axial rotations for one revolution about the sun, and as moreover according to Struve[2] the coefficient of the annual aberration is 20·″4451, the value of the diurnal aberration σ in seconds of arc is

$$\sigma = 20.''4451 \sin 8.''848 \cos \phi = 0.''3212 \cos \phi \ldots\ldots (18)^3$$

which is tabulated hereunder.

TABLE IV.—*Coëfficient of Diurnal Aberration for Different Latitudes.*

Latitude	0°	20°56′	38°53′	51°29′	62°10′	71°52′	90°
Coeff. Diur. Aberr.	0·32″	0·30″	0·25″	0·20″	0·15″	0·10″	0″

The constant of aberration gives at once the effect on the right ascension of a star on the celestial equator when crossing the

[1] The rotational velocity may also be expressed by the formula $\rho \cos \phi$, where ρ is the distance along the normal, from a point whose astronomical latitude is ϕ, to the rotation axis of the eatth. If the equatorial semi-axis be denoted by unity, $\rho = 1 + {}_5\frac{1}{8}{}_6 (1 - \cos 2\phi)$ very approximately, which clearly shews how small the error of the assumption is.

[2] Astronomische Nachrichten, No. 484.

[3] The coëfficient 0·″311 given in Chauvenet's Astronomy, Vol. I., p. 640, and in Clarke's Geodesy p. 190 depends upon Encke's value for the parallax, viz. 8·″57116.

meridian of the observer the result on the apparent declination at the same moment being zero. For a star whose distance from the equator, *i.e.* whose declination is δ, and whose hour angle is T, the effect will be, in right ascension $d\alpha$ say,

$$d\alpha = 0^{s}0214 \cos \phi \sec \delta \cos T \ldots\ldots\ldots(19)$$

and in declination

$$d\delta = 0^{\cdot\prime\prime}321 \cos \phi \sin \delta \sin T \ldots\ldots\ldots(20)$$

the former of which can become considerable only for a star near the pole, and must always be small for a rapidly moving star. The effect of the diurnal aberration on the azimuth and zenith distance of a star may readily be derived from these last equations: it is :—

$$dA = 0{\cdot}321'' \cos \phi \cos A \operatorname{cosec} \zeta \ldots\ldots\ldots(21)$$

$$d\zeta = 0{\cdot}321'' \cos \phi \sin A \cos \zeta \ldots\ldots\ldots(22)$$

in which the angle A should be reckoned from the north line. These quantities are to be added to azimuths and zenith distances computed from the star places given in an ephemeris. The above expressions, though not rigorously exact in the case of the sun, are sensibly so, since the difference between the sidereal and solar apparent rotations is very small. The diurnal aberration may always be neglected with instruments that do not read to within 1″, and is perhaps always negligible in the case of the sun because of the large uncertainty of the refraction and the indifferent definition of the sun's limb. Nevertheless the calculation of the correction is only the work of a minute, and it may at least serve to decide the last figure in the expression of the final result in whole seconds.

8. *Correction for parallax.*—Since an ephemeris to be generally applicable gives only the geocentric positions of celestial objects it is necessary to reduce the results of observations made at a point on the earth's surface also to their geocentric values. This reduction, called the correction for parallax, affects theoretically both the altitudes and azimuths as given by observation, because of the spheroidal form of the earth. Turning first to the correction for *parallax in azimuth*, it is shewn in treatises on spherical

astronomy[1] that if A' denote the apparent, and A the geocentric azimuth, reckoned east or west from the elevated pole, ρ' the radius vector of the point at which the observations are made, ϕ and ϕ' its astronomical and geocentric latitudes, and π' the equatorial horizontal parallax, then

$$\sin (A' - A) = \rho' \sin \pi' \sin (\phi - \phi') \sin A' \sec h \ldots\ldots\ldots(23)$$

in which h is the true geocentric altitude.

The term $\phi - \phi'$, the so-called "angle of the vertical," has a maximum value of about 704″ at latitude 45°, if we accept Clarke's last values for the dimensions of the terrestrial spheroid.[2] The greatest value of π' is about 9″, so that supposing ρ' to be unity, A' to be 90°, the correction can never be more than 0·″0307 sec h; consequently, as in all altazimuth observations for meridian h is never great, the quantity is negligible. Denoting it by α', its mean value is

$$\alpha' = -0{\cdot}''0302 \sin 2\phi \sin A' \operatorname{cosec} \zeta \ldots\ldots\ldots(24)$$

The negative sign denotes that it is always to be subtracted from the azimuthal angle reckoned from the elevated pole.

The *parallax in zenith distance* or altitude, is on the contrary always sensible, except in the case of very small theodolites. According to Newcomb[3] the value of the equatorial horizontal parallax for the earth's mean distance from the sun is 8·″848; and according to Clarke the polar semiaxis is about $\frac{1}{293}$ less than the equatorial, consequently the polar horizontal parallax is about 0·″030 less than the above quantity. 8·″84 may therefore be taken as a general mean value for the entire surface of the earth, which would correspond very nearly to its proper value for a latitude of 30°. Since the semidiameter S of the sun, given for each day in any ephemeris, varies exactly as the parallax—that is to say, both vary reciprocally as the earth's distance from the sun's centre—

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[1] See Chauvenet—Spherical and Practical Astronomy, Vol. I., p. 113, 5th Edition.

[2] Vide "Geodesy," p. 319, Edit 1880.

[3] Washington Observations 1865, Appendix II., p. 29.

and as the sine of the parallax for any geocentric zenith distance[1] ζ, is equal to the sine of horizontal parallax multiplied by the sine of that distance, we have, putting $S_\circ$ for the sun's mean semidiameter, and substituting the arcs of the very small angles for their sines,

$$\pi = -\ 8{\cdot}84'' \frac{S}{S_\circ} \sin \zeta \ldots\ldots\ldots\ldots\ldots\ldots (25)$$

as the general equation for parallax. The negative sign denotes that it is always to be subtracted from the zenith distance. With this factor, the extreme values are 8·″900 and 8·″694, corresponding to the semidiameter values 16·′2922 and 15·′7555 while that for the earth's mean distance is 16·′0197.[2] In the following table the corrections are given with the argument apparent zenith distance[3] corrected for refraction.

TABLE V.—*Sun's Parallax in Zenith Distance.*

Sun's	True Zenith Distances.						
Semidiameter	90°	76° 55′	72° 4′	68° 15′	64° 58′	58° 9′	52° 27′
16′ 0″	8·83″	8·60″	8·40″	8·20″	8·00″	7·50″	7 00″
Corr. for 10″	·092	·090	·087	·085	·083	·078	·073

Sun's	True Zenith Distances.						
Semidiameter	52° 27′	42° 49′	34° 30′	26° 56′	19° 52′	13° 6′	6° 30′
16′ 0″	7·00″	6·00″	5·00″	4·00″	3·00″	2·00″	1·00″
Corr. for 10″	·073	·062	·052	·042	·031	·021	·010

9. *Augmentation of the Sun's semidiameter.*—As the sun's altitude increases, the distance from the observer diminishes, so that when it is in the zenith that distance is less, very approximately by the whole value of the earth's radius. Theoretically therefore, there should be an increase of the geocentric value given in an ephemeris, depending upon the zenith distance. If the distance to the sun be regarded as unity, the earth's radius is sin $\pi_\circ$, that is the sine of the equatorial horizontal parallax, and the diminution of distance is sensibly this quantity multiplied by

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1 Corrected for refraction but not reduced to its geocentric value.

2 According to Auwers.

3 It is really immaterial what zenith distance be used.

the cosine of the zenith distance, consequently the semidiameter S_z at any zenith distance is

$$S_z = \frac{1}{1 - \sin \pi_\circ \cos \zeta} \quad \ldots\ldots\ldots\ldots(o)$$

Hence, rejecting the powers of the small quantity in the denominator higher than the first, and using mean values of the parallax and semidiameters the actual value of the semidiameter will be

$$S_z = S + 0{\cdot}0412'' \cos \zeta \quad \ldots\ldots\ldots(26)$$

The successive hundredths of seconds are the corrections for the following *altitudes*, viz., 14°, 29°, 46° and 73°. It is evident that generally the correction may be ignored without vitiating the results of observations. If computations were carried out to 0·″01 and finally expressed to 0·″1 it might affect the last unit. It is preferable, however, when tabulating the effects of refraction on the sun's diameter, to take cognizance at the same time of the augmentation, and combine these in the tabular value, and this will be done in the subsequent sections.

10. *Contraction of the Sun's horizontal semidiameter by refraction.* —Since the effect of the refraction is to diminish the zenith distance of any point, the extremities of the sun's horizontal diameter will apparently approach one another through refraction by an amount which is equal to the product of the convergency of the vertical circles passing through the extemities, into the displacement by the refraction. The convergency increases as the tangent of the altitudes, and it has already been mentioned that the refraction may be put in the form $r = k \tan \zeta$, in which k, though not absolutely constant, is nearly so, and may be taken from tables of refraction.[1] Consequently we have for s' the contraction of the horizontal semidiameter

$$s' = r\, S \cot \zeta = k \tan \zeta \cot \zeta\, S = k\, S \quad \ldots\ldots\ldots(27)$$

If we take k from a refraction table it must be multiplied by arc 1″ for the value of s in seconds. It is convenient to combine the contraction with the augmentation treated of in the preceding section. Denoting the augmentation term—0·″0412 cos ζ—by g,

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[1] See (*m*) § 6.

and putting s for the contraction diminished by the augmentation, we then have

$$s = s' - g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (28)$$

by means of which the following table is prepared. The geocentric semidiameter $S_\circ$ is supposed to be 16′, bar. 29·6 in. and therm. 48·75° Fahr. The horizontal semidiameter corrected for refraction and augmentation will hereafter be denoted by S, so that $S_\circ = S + s$.

TABLE VI.—*Horizontal Contraction of the Sun's Geocentric Semidiameter.*

$S_\circ = 16'$ Bar. 29·6 in. Therm. 48·75° Fahr.

True Zenith Dist.	0°	20°	47°	70°	75°	85°	87½°	90°
Contraction	0·23″	0·23″	0·24″	0·25″	0·25″	0·23″	0·20″	0·″07

These results are affected by the augumentation and must not therefore be further corrected by (26). For different values of the semidiameter, pressure and temperature, the tabular values require the same factor as c' in (29) hereafter; obviously however, the correction may be ignored because of the smallness of the tabular value.

11. *Contraction of the Sun's vertical diameter by refraction.*— If a great circle be supposed drawn through the true centre of the sun's disc, at right angles to the vertical through the same point, it will divide the *apparent* disc unequally, because the refractions are greater for the lower limb and centre, than for the centre and the upper limb. If therefore, in Fig. 2, § 13, the vertical through the centre C of the sun, be followed downwards, M C from the upper edge to the centre, will always be greater than C M_1 from the centre to the lower edge, and both will be less than the geocentric semidiameter. This contraction of the vertical diameter is sensible to the order of 0·″1 right up to the zenith, within 30° of which the refraction is about 1·″1 per degree. The difference between the upper and lower semidiameters however, only becomes sensible as we closely approach the horizon—as is apparent in Table VII. hereunder. As in the preceding section, it is also convenient to include the effect of augmentation, which slightly reduces the contraction, because in this way the apparent form is

immediately obtained with the zenith distance as argument. In computing therefore the results given in the table the augmentation has been taken into account ; the geocentric semidiameter is taken as 16′, reduced barometric pressure 29·6 inches, *i.e.* at 32° Fahr. and air temperature 48·75 Fahr.; these being the pressure and temperature of no correction in Bessel's refractions. This reduced contraction will hereafter be denoted by c'.

TABLE VII.—*Vertical Contraction of the Sun's Semidiameter.*

$S_\circ$ = 16′. Bar. 29·6 in. Therm. 48·75 Fahr.

Zenith Distances Corrected for Refraction.

Centre of Sun	0°	15°	30°	40°	50°	55°	60°	65°	70°
	″	″	″	″	″	″	″	″	″
Contr. Upper Semidiameter	0·23	0·24	0·32	0·46	0·62	0·78	1·03	1·44	2·19
Ditto, Lower	0·23	0·24	0·32	0·46	0·63	0·79	1·05	1·47	2·25
Difference	—	—	—	—	0·01	0·01	0·02	0 03	0·06

Zenith Distances Corrected for Refraction.

Centre of Sun	75°	78°	80°	81°	82°	83°	84°	84½°	85°
	″	″	″	″	″	″	″	″	″
Contr. Upper Semidiameter	3·72	5·57	7·67	9·19	11·20	13·90	17 61	20·00	22·92
Ditto, Lower	3·84	5·80	8 03	9·65	11·84	14·75	18·79	21·44	24·77
Difference	0·12	0·23	0·36	0·46	0·64	0·85	1·18	1·44	1·85

NOTE.—See also Table IX. § 19, for contractions with the argument apparent zenith distance.

For other values of the semidiameter, and other barometric and thermometric readings, the tabular quantities will require correction. If $S_\circ$ denote the semidiameter *in minutes*, given in the ephemeris for the time of observation, and B and τ respectively, the barometer reading reduced to 32° Fahr., and the air temperature in Fahr. degrees, then the true contraction c may be found from the tabular contraction c' by the following formula, the last two factors of which also approximately express the barometric and thermometric correction of the refraction,

$$c = c' \frac{S_\circ}{16} \cdot \frac{B}{29{\cdot}6} \cdot \frac{461{\cdot}75}{413 + \tau} \quad \ldots\ldots\ldots\ldots\ldots\ldots (29)^1$$

Below 85° zenith distance the sun's form is generally so irregular

[1] The ratio $S_\circ/16$ as a factor is not rigorously accurate but will nevertheless not involve an error of 0·01″ even at 85° zenith distance.

that no confidence can be placed in any theory of its apparent contraction, or in the value of the refraction; and it may further be observed that the imperfect definition of the limbs at low altitudes renders accurate observation impossible, so that the order of the difference between the upper and lower semidiameters, even at 85° zenith distance, is practically almost negligible. The reduced vertical semidiameter will hereafter be denoted by S_1.

12. *Elliptical figure of the Sun's image.*—Since the variation of the refraction for small variations of zenith distance is nearly linear, it follows that the form of the sun is nearly elliptical. The departure from the outline of a perfect ellipse is perhaps always negligible, as will be seen from the following comparison of an extreme case between the outline approximately computed on the elliptical assumption and that obtained from the refraction theory by supposing the air temperature and pressure to be that of no correction in Bessel's table, and the *true* altitude of the sun's centre to be 5°. The upper limb is taken for comparison. In Fig. 2 let the line C N be trisected, and parallels be drawn to the verticals through the centre, from the points u, v, so found. Then neglecting horizontal contraction, and assuming the refraction to act in the direction of these parallels, which is nearly true, we have since M M′ is 22·″92

By refraction	U U′ =	21·67″	V V′ =	17·25″
By ellipse		21·61		16·09
Difference		0·06		0·16

This order of difference, viz. one or two tenths of a second of arc, is really negligible because of the imperfection of definition at so low an altitude. The difference however may easily be taken into account as a small correction on the hypothetic elliptical form, as shewn in the more exact treatment of the next section. What the illustration establishes is that, at least to a first approximation, the hypothesis of an elliptical outline for the sun's image is justified.

13. *Contraction of inclined semidiameters and departure from elliptical form.*—We have seen that while the contraction of the

horizontal diameter is sensibly constant at all altitudes, that of the vertical diameter greatly varies with the altitude, so that regarding the sun's apparent figure, as an ellipse, the eccentricity of the figure will continually diminish as the zenith is approached, the circular form being attained only when the centre is at the zenith. We shall have occasion to find the length of an inclined semidiameter. This may most readily be done by finding a quantity such that if subtracted, not from the geocentric semidiameter, but from the contracted horizontal semidiameter it will give the value of the inclined semidiameter as affected by refraction and augmentation. Denoting the values in Tables VI. and VII., § 10 and § 11, by s and c' as before, we have for the reduced horizontal and reduced vertical semidiameters respectively,

$$S = S_0 - s\ ;\ S_1 = S_0 - c\ ;$$

consequently, if we use c to express the difference of the semidiameters, the value of c is given by

$$c = S - S_1 = c' - s \quad \ldots\ldots\ldots\ldots\ldots\ldots (30)$$

that is to say, c is the difference of the reduced horizontal and vertical refractions.

Ignoring primarily the defect of the elliptical hypothesis, let C P the inclined semidiameter as affected by refraction and augmentation, see Fig. 2, be denoted by S_2; the inclined contrac-

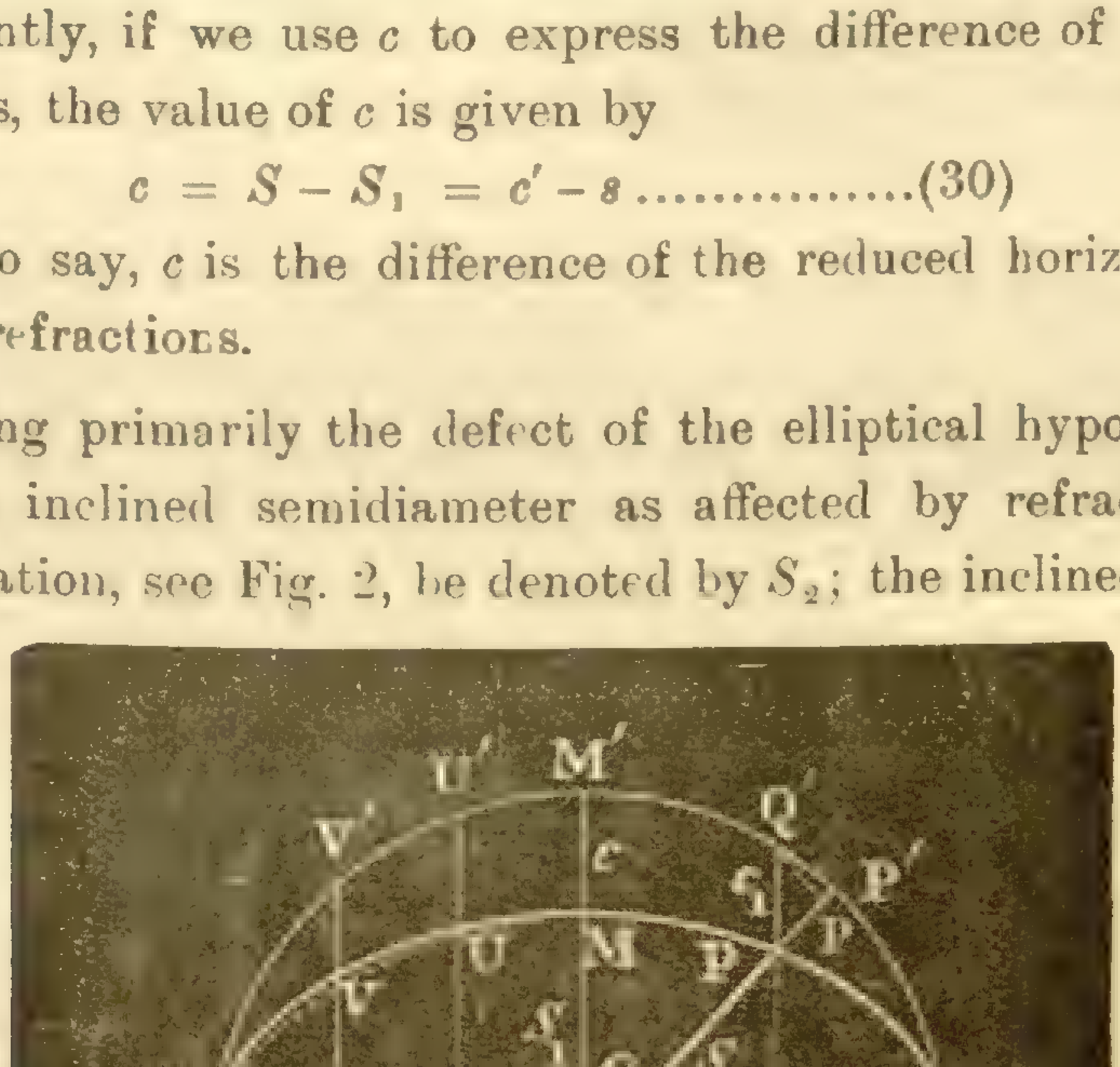

Fig. 2.

tion P P′ by c_2; the angle of the radius vector C P, *i.e.*, the angle M C P by θ; and the intercept P Q′ between the two arcs, of a line parallel to C M by c_1, then we have by geometry

$$S_1/(S_2 \cos \theta) = c/c_1 \text{ ; or } c_1 = (S_2 c \cos \theta)/S_1 \ldots\ldots\ldots(p)$$

and p Q′ being at right angles to C P

$$c_2 = \text{P p} + \text{p P}' = c_1 \cos \theta + (c_1^2 \sin^2 \theta)/(2S - \text{etc.}) \ldots (q)$$

with a high order of precision.[1] By a method of successive approximations the following values of c_1 and c_2 may be derived, viz.,

$$c_1 = c \cos \theta \left[1 + \frac{c}{S_1} \sin^2 \theta \left(1 - \tfrac{3}{2} \frac{c}{S_1} \cos^2 \theta\right)\right] \ldots\ldots\ldots\ldots(31)$$

$$c_2 = c \cos^2 \theta \left\{1 + \tfrac{3}{2} \frac{c}{S_1} \sin^2 \theta \left[1 + \tfrac{1}{8} \frac{c}{S_1} (1 + \cos^2 \theta)\right]\right\} \ldots\ldots\ldots(32)$$

The second term, of this value for the contraction of the inclined semidiameter, is generally negligible. It may be reëxpressed thus for the purposes of calculation,[2]

$$\frac{3c^2}{2S_1} \sin^2 \theta \cos^2 \theta = \frac{3c^2}{8S_1} \sin^2 2\theta \ldots\ldots\ldots(33)$$

and is therefore obviously a maximum for $\theta = 45°$. Resuming the previous example, in which the true altitude of the sun's centre is taken as 5°, and the difference of the contractions consequently 22·″69, we have $S_1 = 15' 37{\cdot}''01$, hence the value of the term is 0·″21. This quantity is of the same order as the difference, referred to in the preceding section, between the real image by refraction, and that deduced from the assumption of elliptical form. If the second term therefore be regarded as appreciable, the defect of the elliptical hypothesis must be considered at the same time.

In order to illustrate the difference between the elliptical outline and the figure given by the refraction theory, let us revert to the case where the sun's centre has a true zenith distance of 85°, its apparent zenith distance being therefore 84° 50′ 28·″36 at the

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[1] The more complete expression for the denominator of the last term in (q) is $2S - (c_1^2 \sin^2 \theta)/2S - \text{etc.}$, a continued fraction.

[2] The computation of the squares of sines and cosines is facilitated by using the formulæ $\sin^2 a = \frac{1}{2}(1 - \cos 2a)$ and $\cos^2 a = \frac{1}{2}(1 + \cos 2a)$.

temperature and pressure of no correction in the Besselian refraction table. For the sun's semidiameter the difference between plane and spherical coördinates can never reach 0″005, hence we may use the former without sensible error. By taking points on the sun's edge at $22\frac{1}{2}°$, 45°, $67\frac{1}{2}°$, and 90° from the intersection of the vertical through its centre, with the upper and lower limbs, computing very rigorously the refractions thereat, remembering that these refractions are displacements, not in lines parallel to the central vertical, but on the verticals through the several points; we obtain the coördinates of their positions in the sun's refracted image. Then by describing two semiëllipses with the contracted horizontal semidiameter as major axis, and the upper and lower vertical contracted semidiameters as minor axes; and computing the ordinates for points thereon whose abscissæ, measured on a great circle at right angles to the vertical through the image of the sun's centre, are the same as in the refraction computation, we are able to compare the two results, and thus determine the error of the elliptical assumption. Taking the image of the sun's centre as the origin of the coördinates we obtain the following results in which + denotes increase of zenith distance, and the angles from the vertex are for the real sun, not its image.

Upper Limb.

Angle from vertex	0°	$22\frac{1}{2}°$	45°	$67\frac{1}{2}°$	90°
	″	″	″	″	″
Abscissæ	0	367·29	678·66	886·71	959·77
Ord. by Refract.	−937·08	−865·69	−662·43	−358·40	−0·01
Ord. by Ellipse	same	−865·75	−662·61	−358·60	−0·00
Difference	nil	+0·06	+0·18	+0·20	−0·01

Lower Limb.

Angle from vertex	90°	$112\frac{1}{2}°$	135°	$157\frac{1}{2}°$	180°
	″	″	″	″	″
Abscissæ	959·77	816·71	678·66	367·29	0
Ord. by Refract.	−0·01	+358·11	+661·50	+864·11	+935·23
Ord. by Ellipse	−0·00	+357·89	+661·31	+864·04	same
Difference	−0·01	−0·22	−0·19	−0·07	nil

The circumference of the ellipse therefore lies outside the sun's refracted disc, on the upper limb, and inside of the lower. In Fig. 2, the dotted line represents diagrammatically the real boundary of the sun's disc, the firm line its boundary on the assumption that its circumference is an ellipse. The maximum difference between the upper and lower difference is 0·″02; by pushing the computation farther it would be seen that their ratio is almost exactly as the upper and lower vertical contractions.

For their values in the directions of the radii vectores, these vertical differences between the sun's disc and the circumference of the ellipse, must be multiplied by cos θ.[1] In this way we empirically find that the difference between the polar coördinates of the refracted disc and the ellipse of the same axes is very accurately[2] represented by the expression $k \sin^2 2\theta$, in which $k = 0{\cdot}0057\ c$. This deviation depends mainly upon the fact that the variation of the refraction is not absolutely linear, particularly at low altitudes. It becomes sensibly so, however, for the sun's diameter, at as low an altitude as 10°; at which the compression has diminished to about one-third of what it is at 5°, vide Table VII., § 11. A little close consideration will show that the variation of this term is of the same order as (33), and that it rapidly becomes negligible with increase of altitude. It is convenient therefore, to combine it with that expression, by *adding* for the *upper* limb, and *subtracting* for the *lower*, $\frac{3}{5}$ of the coëfficient.[3] Hence it becomes $\frac{3}{8}(1 \pm \frac{3}{5})$, and the whole expression for the contraction of the reduced or contracted horizontal semidiameter, may be written

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[1] The result though of course theoretically only approximate, is perfectly exact to the order of the quantities under consideration. We may even take $\theta = 22\frac{1}{2}°$ etc. in the case considered.

[2] The mean results are ·061, ·130, ·079; the expression gives ·069, ·135, ·065.

[3] The value of $\frac{3}{8}\ c^2/S_1$ is for the mean value of c for the upper and lower contracted semidiameters is 0·″223 and of k 0·″135, that is very approximately $\frac{3}{5}$ of that amount.

$$\left.\begin{aligned} c_2 &= c\cos^2\theta + \tfrac{3}{5}\,\frac{c^2}{S_1}\sin^2 2\theta, \text{ for } \theta = 0^\circ \text{ to } 90^\circ \\ c_2 &= c\cos^2\theta + \tfrac{3}{20}\,\frac{c^2}{S_1}\sin^2 2\theta, \text{ for } \theta = 90^\circ \text{ to } 180^\circ \end{aligned}\right\} \ldots(34)$$

In the following table are given the values (i) of the first term of the contraction of inclined semidiameters, on the assumption that the apparent horizontal semidiameter, that is as reduced by refraction, is 16′, and that the difference between the horizontal and vertical contractions is 20″: and (ii) also the values of the corrected second term which is always to be added, the upper number denoting this second correction for the upper, and the lower number the second correction for the lower limb of the sun. For any other value of the difference of the horizontal, and vertical contractions, multiply the first term by the ratio of contraction to 20″, *i.e.* by $c/20''$, and the second term by the square of that ratio and add the results. For a different value of the contracted horizontal semidiameter, multiply the quantity so found from the table, by the ratio of the reduced horizontal semidiameter to 16′. The corrections to the tabular values can generally be applied by mere inspection.

TABLE VIII.—*Contractions of inclined semidiameters of the Sun: the contracted horizontal semidiameter being 16′, and vertical semidiameter 15′ 40″.*

Angle with vertical.	Contraction.		Angle with vertical.	Contraction.		Angle with vertical.	Contraction.	
°	″	″	°	″	″	°	″	″
0	20·00	+ ·00	30	15·00	+ ·19	60	5·00	+ ·19
180		·00	150		·05	120		·05
5	19·85	·01	35	13·42	·23	65	3·57	·15
175		·00	145		·06	115		·04
10	19·40	·03	40	11·74	·25	70	2·34	·11
170		·01	140		·06	110		·03
15	18·66	·06	45	10·00	·26	75	1·34	·06
165		·02	135		·07	105		·02
20	17·66	·11	50	8·26	·26	80	0·60	·03
160		·03	130		·06	100		·01
25	16·43	·15	55	6·58	·23	85	0·15	·01
155		·04	125		·06	95		·00

For altitudes greater than 15° it will always be sufficient to use the following formula for the radius vector, viz.

$$S_2 = S - \tfrac{1}{2}\, c\,(1 + \cos 2\theta) \ldots\ldots\ldots\ldots\ldots\ldots (35)$$

the derivation of which from (32) is obvious. This formula neglects the secondary term in the expansion for the ellipse, and assumes that the difference between the refracted and elliptical forms is negligible.

14. *Elliptical image of the sun tangent to two diaphragm wires inclined at any angle.*—As the sun is often observed at the moment it is tangential to two diaphragm wires, it is necessary to so correct the instrumental record as to obtain the altitude and azimuth of the *image* of the sun's centre,[1] for it is to that point only that the tabulated places in an ephemeris refer. The diaphragm wires cannot be assumed to be in perfect adjustment, consequently we shall suppose them to be slightly out of position, in order to make the treatment of the case quite general.

In Fig. 3 let M C denote a vertical line drawn through the centre C of the sun's elliptical image N Q M P, tangent at the points P and Q to the diaphragm wires I P, I Q. Since C M and

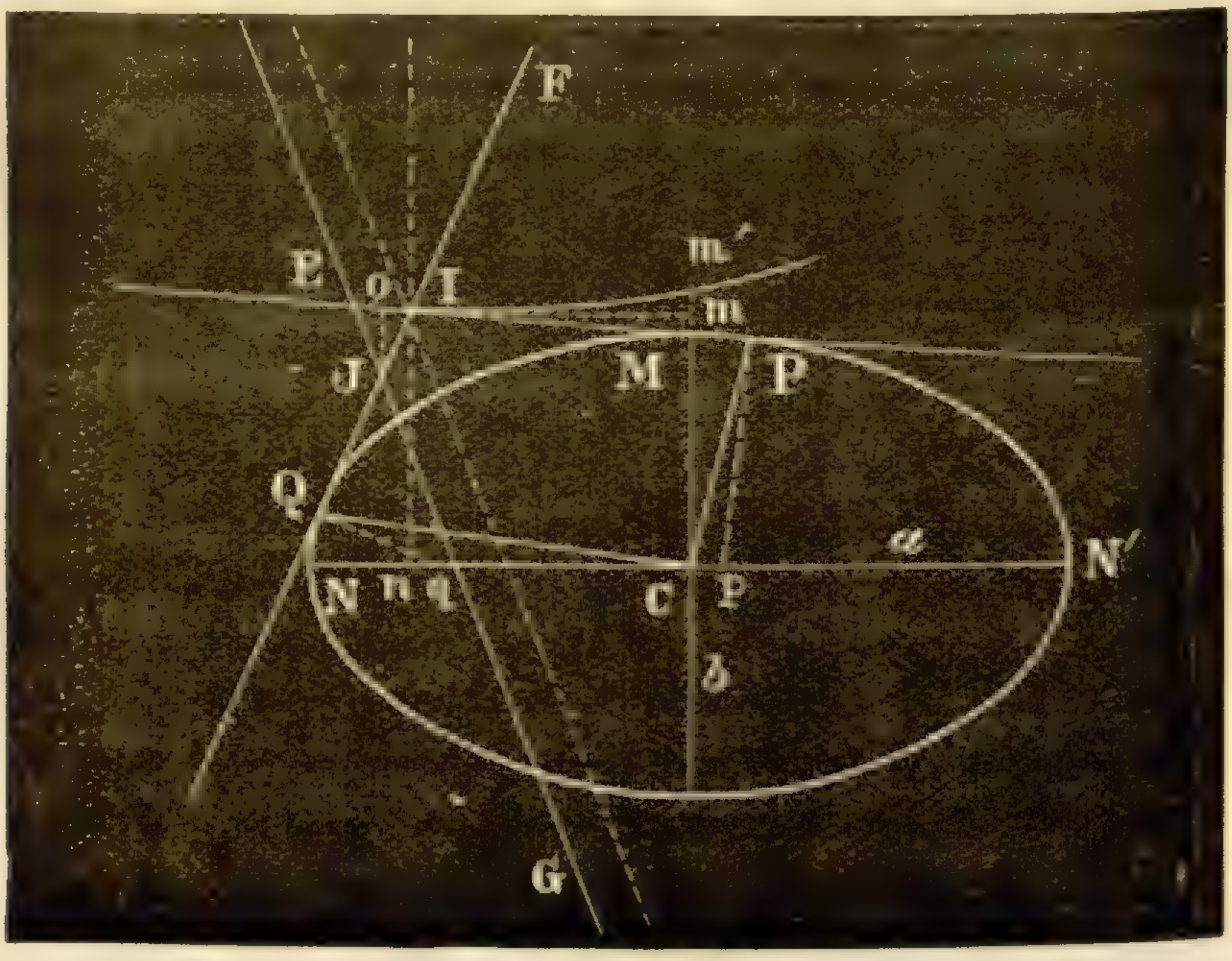

Fig. 3.

[1] Not of the centre of its image.

C N can never be greater than about 16′ each, it is evident that the relation between C and I may be ascertained with sufficient rigorousness by treating the problem, so far as that relation is concerned, as plane instead of spherical.[1] The dimensions of the elliptical image, together with the magnitudes of the angles at I and J, and their relation to a vertical drawn through this latter point, admit of a complete determination of the quadrilateral I P C Q. It may be remarked that for the system of wires illustrated in the figure, the angle Q I P is generally about 110°, and Q I makes an angle of about 20° with the vertical. I P should be at right angles to a vertical passing through J : with ordinary care in adjustment an error of 1° in that respect will rarely be found. If P p and Q q be normals to the curve, the angle at p will consequently be between 89° and 91°, and at q about 20°. It is always intended that the intersection J shall be coincident with that at I : this is never perfectly realized so that the intersections must be treated as non-coincident.

An expression will hereafter be required for the difference of direction between the normals and the radii vectores from P and Q. For convenience put $a = S$, the semidiameter from the ephemeris for the date of observation, corrected for augmentation and horizontal refraction : and put also $b = S - c = S_1$ viz. the vertical semidiameter similarly corrected ; then designating the angles at C, P, Q, p and q as follows,—

$$\text{P p N}' = \xi\,,\ \text{P C N}' = \xi'\,,\ \text{C P p} = \xi - \xi' = x \text{ say},$$

$$\text{Q q N} = \chi\,,\ \text{Q C N} = \chi'\,,\ \text{C Q q} = \chi - \chi' = y \text{ say},$$

we have exactly, from the geometry of the ellipse,

$$\tan \xi' = \frac{b^2}{a^2} \tan \xi \ldots\ldots\ldots\ldots\ldots\ldots (r)$$

and an identical expression in χ. Let

$$\mu = \left(\frac{b^2}{a^2} - 1\right) \Big/ \left(\frac{b^2}{a^2} + 1\right) = -\frac{c}{S} - \tfrac{1}{2}\frac{c^2}{S^2} + \tfrac{1}{4}\frac{c^4}{S^4} \text{ etc} \ldots (s)$$

then from Lagrange's development we may obtain

$$x = \xi - \xi' = -\mu \sin 2\xi - \tfrac{1}{2}\mu^2 \sin 4\xi - \text{etc} \ldots\ldots\ldots\ldots (t)$$

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[1] This can in no case involve an error of 0·″005 as previously pointed out.

and the corresponding expression in χ, which may also be written

$$y = \chi - \chi' = -\mu \sin 2\chi (1 + \mu \cos 2\chi + \text{etc.}) \ldots\ldots\ldots (u)$$

It is convenient to replace μ by terms in c/S, thus from (s) and (u) we have, on rejecting as certainly negligible the powers of this fraction higher than the second,

$$x = \frac{c}{S} \sin 2\xi \left[1 - \frac{c}{S} (\cos 2\xi - \tfrac{1}{2})\right] \ldots\ldots\ldots (36)$$

and a similar expression for y containing χ instead of ξ. We shall shew that even the secondary terms in these equations for x and y, are also *always* negligible in the application with which we are dealing. Evidently the value of (36) is a maximum for $\xi = 45°$, when $\cos 2\xi$ is zero, and the whole value of the secondary term is $+c^2/2S^2$, as the sine factor is then unity. An altitude of $5°$ may be regarded as the lowest at which an observation should be made, in which case c/S is about $22''.69/960''$ or $\frac{1}{42}\cdot 3$: consequently the error of omitting the secondary term can never amount to $\frac{1}{3570}$ for any system of wires, and is about that amount, or $0''.26$ for the angle Q C N in Fig. 3, a quantity which is quite negligible since its effect will never be more than $0''.001$ in the final results. We may therefore always write the preceding equations in the simpler form

$$x = \frac{c}{S} \sin 2\xi\,,\ y = \frac{c}{S} \sin 2\chi \ldots\ldots\ldots (37)$$

If x and y are required in degrees, minutes or seconds of arc, the quantities must be multiplied by the number of degrees, minutes or seconds in a unit of circular measure, as for example, by $3437'.7$ for the result in minutes.

We have supposed C M to be vertical because the elliptical outline is then symmetrically situated with respect thereto. The relations of the lines I P, I Q to the verticals drawn through I or J—since these last are nearly identical—are ascertained by observation: but the convergency of the verticals, through say C and I, is a function of both the semidiameter and contraction, as well as of the directions of the lines, I P, I Q. This convergency however, is considerable only for high altitudes—*i.e.*, when the ellipticity is extremely small—and is very small when the ellipticity

is marked, its neglect therefore will not sensibly prejudice the evaluation of the lengths of the radii vectores C P, C Q. With regard to the former it is evident from (32), § 12, and from an inspection of Table VIII., that we can take C P = C M without sensible error if I P be not more than 1° or 2° from the perpendicular to the vertical through I. For the error of such an assumption will obviously be

$$c \sin^2 \theta = \tfrac{1}{2} c \text{ vers } 2\theta,$$

hence if the vertical contraction amount even to 25″, the corrections would amount in the cases supposed, only to 0·″008 and 0·″030 respectively, the former even, being an extreme case. Again with respect to C Q, it may for the same reason be taken equal to the contracted horizontal semidiameter, if I Q be nearly vertical, as A B, Fig. 4, hereinafter. If however the wire be inclined about 20° to the vertical as in Fig. 3, an error of 1° in the estimation of that angle will cause an error of only 0·″22, for a vertical contraction of 20″; and as the convergency can amount only to about 1′, it is clear that its neglect will cause an error of not more than 0·″004 in the length of the line C Q. We may therefore rotate the axes of the ellipse through the arc equal to the convergency without sensible error. In regard to this it ought perhaps to be remarked that as the form of the sun's image approaches a circle the effect of rotation becomes more and more negligible, and is of course absolutely indifferent for a circular image. We have seen in Table VII., § 11 that the ellipticity is only about $\frac{1}{125}$ at an altitude even so low as 10°: hence it is necessary to consider the consequences of rotating the axes, only for the altitude corresponding to the conditions of most marked ellipticity, or say practically at an altitude of 5°.

Rejecting very small quantities, the rotation equal to the convergency ν, to make C M parallel to the vertical through J, is given by the equation

$$\nu = (S \text{ cosec } \gamma - S_1 \cot \gamma + j) \cot \zeta \quad \text{approx....}(v)$$

γ denoting the angle F I P, and j the rectangular distance between the verticals through J and I. Taking $S = 16'$, $S_1 = 15\frac{2}{3}'$, $\gamma = 70°$,

and j say $\frac{1}{3}'$, we have for $\zeta = 85^\circ$, $\nu = 11\frac{2}{3} \cot \zeta = 1'.02$. We may therefore, as before indicated, and without being involved in an error of even $0''.01$, always take ξ *as the angle between the horizontal wire and the vertical through the intersection* J *of the inclined wires, and* χ *as the angle between the inclined wires and the same vertical.* This simplifies the solution.

Through the point I, Fig. 3, draw I n parallel to the vertical through J, and I m at right angles thereto: then ξ = angle P I n,[1] and χ = angle Q I n. The angles at C, I, P and Q of the quadrilateral are respectively $\gamma + x + y$, $180^\circ - \gamma$, $90^\circ - x$, and $90^\circ - y$. If the line I P be inclined upwards, we write $-x$ for $+x$ in the first of these quantities and *vice versa* in the third: the others remain of course unchanged. By an appropriate construction[2] the values of I n, I m may be written down almost by inspection. Calling the former, that is the vertical one X, and the latter or horizontal one Y, and the lines C P, C Q respectively S_2 and S_3, the result, after some slight simplification, is

$$\left.\begin{aligned} X &= S_3 \cos y \,(\sin \chi - \cos \chi \cot \gamma) + S_2 \cos x \cos \chi \operatorname{cosec} \gamma \\ Y &= S_3 \cos y \sin \xi \operatorname{cosec} \gamma + S_2 \cos x \,(-\sin \xi \cot \gamma \mp \cos \xi) \end{aligned}\right\} \quad (38)$$

In the last term of the value for Y the lower, *i.e.*, the + sign, is to be taken, if the point P is *above* the line I m: the minus sign is for the case illustrated in the figure. X is unaffected as regards its signs; the variation in the angle γ consequent upon variation in the direction of I P, produces the requisite modification of its value.

If the line I P be within say two degrees of the horizontal, 2ξ lies between 176° and 184°: hence from (37) we see that x will not be numerically greater than $\frac{1}{42}$ of 4°, that is than $6'$, when the zenith distance is 85° or less. The error of putting 1 for its cosine is consequently not greater than about one half millionth.

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1 Or its supplement, the former in the figure. It is perhaps somewhat safer to take it always as shewn.

2 As for example, by dropping the perpendiculars C U, C V say—not shewn in Fig. 3—from C on to I P and I Q, and again from U on to C V, U W say, and from I on to U W.

It has also already been remarked that the vertical contracted semidiameter may be used for the length C P, vide p. 337, this section, and it may be noticed that the maximum value of y, assuming χ to be 20°, and the altitude to be 5°, is only about $52\frac{5}{6}'$, so that the error of assuming its cosine also to be unity is only about $\frac{1}{8\,4\,7\,0}$. This would involve an error of 0·″33 in the value of Y, and nothing sensible in that of X,[1] consequently the equations (38) may, for the system of wires represented in Fig. 3 always be put in the form

$$\left.\begin{aligned} X &= S_3\,(\sin\chi - \cos\chi\cot\gamma) + S_1\cos\chi\operatorname{cosec}\gamma \ldots\ldots\ldots \\ Y &= S_3\cos y\sin\xi\operatorname{cosec}\gamma - S_1\,(\sin\xi\cot\gamma \pm \cos\xi) \ldots\ldots \end{aligned}\right\} (39)$$

the plus sign in the last written term being taken for the case illustrated in the figure, and the minus sign when P is above the line I m. These equations do not involve an error of 0·″01. When the altitude is 15° or more, the substitution of unity for $\cos y$ will not involve an error of 0·″01 in the value of Y. Hence we see that *for any altitude from 15° upwards, the image of the sun may be assumed to touch the wires at points determined by letting fall perpendiculars thereon from the image of the sun's centre.* And this may always be assumed for small theodolites, or for such as do not read to less than 1″.

If the wire I P be perfectly at right angles to the vertical through J,

$$X = S_1, \text{ and } Y = S_3\cos y\operatorname{cosec}\gamma - S_1\cot\gamma \ldots\ldots\ldots\ldots (40)$$

The desirableness of securing exact adjustment is very obvious on comparing this last formula with (38) or (39).

In Fig. 3 let I m′ represent an almucantar drawn through I: then in applying formula (7) for its computation, we may take m m′ = m say, and

$$m = \tfrac{1}{2}\,(S\operatorname{cosec}\gamma - S_1\cot\gamma)^2\cot z \ldots\ldots\ldots\ldots\ldots (w)$$

For $\gamma = 70°$ this correction will amount only to 1·″10 cot z, a formula by means of which m m′ may generally be computed for

[1] If the I P wire be horizontal the value of the S_3 term in X is zero.

the system of wires to which reference has been made: z should preferably be the apparent zenith distance of C, not of I.[1]

The correction for the difference of altitude between I and the point o in Fig. 3, may be supposed to have been ascertained by previous investigation. Let it be denoted by i: the position of the image of the sun's centre will then be completely determined; and if z' denote the zenith distance given after the application of merely instrumental corrections, the *apparent zenith distance* z, of C, is

$$z = z' \pm i + m \pm X \ldots\ldots\ldots\ldots\ldots\ldots(41)$$

To this must be applied the corrections for refraction, parallax, etc., for the result z is what would have been given had it been possible to have "bisected" a mark defining on its diametral plane, the sun's centre.

Let the distance of I from the vertical passing through J be denoted by j as before, see (v): then A' being the corrected instrumental record, the true direction A of the image of the sun's centre will be

$$A = A' \pm (j + Y) \operatorname{cosec} z \ldots\ldots\ldots\ldots\ldots\ldots(42)^2$$

z is the apparent zenith distance of the sun's centre, as found by (41)

15. *Elliptical image of the sun tangent to perpendicular and horizontal diaphragm wires.*—When the sun is so observed as to

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1 Strictly the almucantar should start on N C at a point vertically below J, see Fig. 3: or else a line should be drawn from C perpendicular to the almucantar, and the difference between its length and that of C m taken as the correction m. By using z instead of z' see (41) hereafter, the correction becomes very nearly exact: practically however, either may be employed, since the altitudes in the case considered are always small. Even when z is 45° the difference can amount only to $0.''02$.

2 This formula is of course not strictly exact: j ought to be multiplied by the cosecant of the zenith distance of J: the error however is quite negligible. And again the substitution of an expression of the form $a = k\,b$, instead of the proper spherical formula $\tan a = k \tan b$, k being cosec x and b, $j + Y$, is also theoretically defective. The equivalent of the proper formula is

$$a = k\,b\,[1 - \tfrac{1}{3}\,b^2\,(k^2 - 1) \text{ etc.}],$$

but the error committed is easily seen to be quite insensible.

be tangent to two wires one of which is nearly vertical and the other nearly horizontal—see A I C, position 3 Fig. 4 hereinafter—the solution is simplified. It has been shewn in the preceding section that when the defect from verticality and horizontality is small, the perpendicular distance from the image of the sun's centre to the wires may always be regarded as equal to the corrected semidiameters, viz., S and S_1, and so also the lines drawn from that point parallel to the two wires. ξ and χ having the same signification as in the preceding article, we shall have

$$\left.\begin{aligned} X &= S_1 \cos \chi \pm S_3 \cos \xi \ldots\ldots \\ Y &= S_3 \sin \xi \mp S_1 \sin \chi \ldots\ldots \end{aligned}\right\} \ldots\ldots (43)$$

$$m = \tfrac{1}{2} Y^2 \cot z \ldots\ldots (44)$$

For the position illustrated in Fig. 3 the upper sign is taken in X and Y when the inclination of the wires is in the same direction as shewn in the figure.

16. *Elliptical image of the sun tangent to one diaphragm wire.*—The observation of the sun when tangent to one wire, the intersection therewith of the other wire marking the point of tangency, gives only one coördinate with precision. With telescopes of high power, it is nevertheless the only possible method. We shall later return to this point. The typical positions for observation are illustrated in Fig. 4 hereinafter, § 18. See 1 and 2 tangent at I, and also 2 at J, to the line bisecting the angle E J F.

For the case represented by 1 in Fig. 4, the tangential point I is clearly similar to P in Fig. 3. Let ξ'' denote the error of adjustment of the horizontal wire, so that $\xi'' + \xi = 90°$, its sine then will be very small, hence from (37) we may write

$$\left.\begin{aligned} X &= S_1 \cos \left[\xi'' \left(1 + \frac{2c}{S_1}\right)\right] \ldots \\ Y &= S_1 \sin \left[\xi'' \left(1 + \frac{2c}{S_1}\right)\right] \ldots \end{aligned}\right\} \ldots\ldots (45)$$

X and Y being as before, respectively the vertical and horizontal corrections. Y cosec z, the azimuthal correction, is of very doubtful value.

For the case marked 2 in Fig. 4, the tangential point I or J is similarly Q in Fig. 3. χ will denote the angle between A B, or

the dotted line a b Fig. 4, and the vertical through I or J in the same figure.

$$\left.\begin{aligned} X &= S \sin [\chi (1 - \frac{2c}{S})] \ldots \\ Y &= S \cos [\chi (1 - \frac{2c}{S})] \ldots \end{aligned}\right\} \ldots\ldots (46)$$

X, the correction in altitude, is of very doubtful value; it would be idle to insert the correction m in such a case, as it rarely amounts to more than a few tenths of a second, and observations of this type are not of sufficient precision to justify it.

17. *Measurement of the angles between the diaphragm wires.*—This measurement must be accurately made in order to obtain the best possible results from the preceding formulæ; it can be effected in the following manner: Let a large sheet of Bristol board, ruled with a set of close very fine and accurately parallel lines, be placed at right angles to, and with its centre in, the prolongation of the vertical or azimuthal axis of the theodolite and sufficiently far away to secure a distinct image by focussing. This will require the telescope to be placed in the direction of the axis, *i.e.* to be set at $z = 0°$, and the diagonal eye-piece to be used. Setting the azimuthal circle at zero, rotate the outer azimuthal axis until on moving the telesecope vertically, *i.e.* in zenith distance, the intersection of the wires moves in a direction perfectly parallel to the ruled lines; and clamp in this position. Reset to the reading $z = 0°$ and rotate the inner azimuthal axis, until each wire becomes successively parallel to the ruled system of lines. The successive readings give the angles between the wires and the vertical. The mean of a series of observations would of course be taken.

A second but less exact method is the following:—Set up the instrument in the ordinary manner with the telescope pointing horizontally, and at right angles to a vertical surface on which a Bristol board has been suitably placed. With a fine pricking point mark on this the intersection point or points, and the outer edges of the diaphragm wires. Rotating the azimuthal axis so that the telescope rotates azimuthally only, mark also the trace of the intersection point on each side of the mark first made. This last

will give the relation of each wire to a truly horizontal line. In a second series of markings let the telescope be rotated vertically and mark the trace of the intersection point vertically above and below the original mark : this similarly gives the relation to the vertical line directly. By means of a protractor, or better still by triangular scaling and computation, the angles may be measured: the mean of the two, or of a series, being taken.

18. *On methods of observation generally.*—There are really only two radically distinct methods of solar observation for the determination of the meridian (i) the method of equal altitudes, and (ii) that of simple altazimuth observations. In neither can the centre of the sun be directly observed, so that it has to be derived from observations made of the position of its circumference. The systems of diaphragm wires ordinarily found in theodolites are either A B and C D, or E G, F H and C D intersecting respectively at I and J, see Fig. 4. It is always intended that A B should be

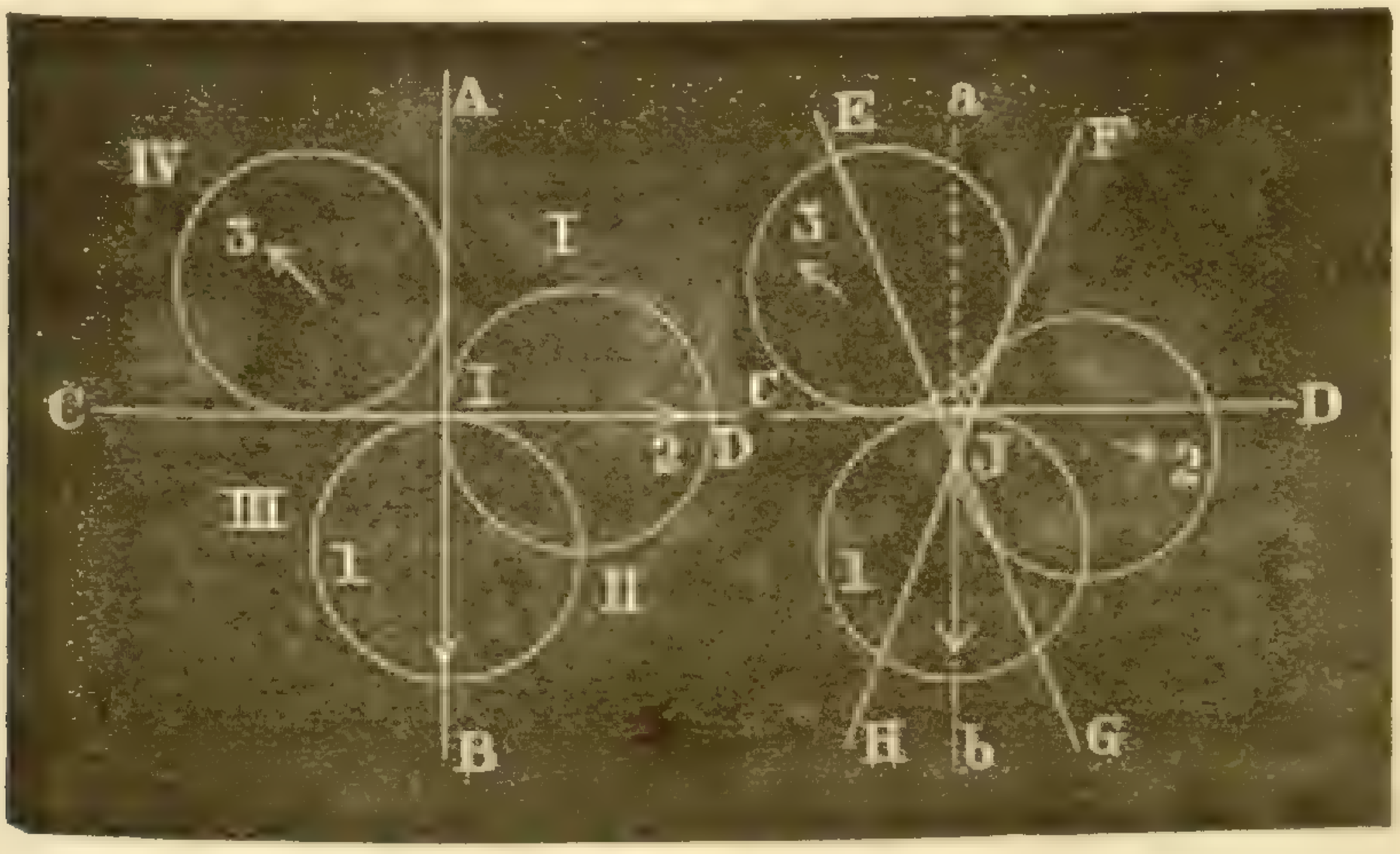

Fig. 4.

vertical and C D at right angles thereto; that E G and F H should be symmetrically situated with respect to a vertical line a b, to which also C D should be perpendicular; and that the intersection J should be on the wire C D. These conditions are but rarely even approximately fulfilled, and should be investigated: the defects are often quite appreciable. The sun is observed in positions typified by the representations in the figure: see also

Fig. 3 in § 14. With telescopes of high power the types of observation marked 1 and 2 are alone possible, since the field of view is very limited: with low powers, type 3 is also possible. Some practice is necessary to observe simultaneously the two tangencies of this last type; the observation of a single tangency is much less fatiguing. It has already been pointed out however in § 16, that one of the results of the single tangency observation is not very reliable; for example, the positions marked 1 in Fig. 4 determine the altitude well, and the direction indifferently: 2 on the contrary gives good results for direction, and indifferent ones for altitude. With an electrochronograph the difficulty arising from this circumstance can be obviated as hereinafter shewn, but without such an accessory it may be necessary to determine which of these types of observations, *i.e.* 1 or 2, is to be preferred. This preference will depend really upon three things, viz.:—(i) the ratio of the probable error of the measurement of a zenith distance to that of an azimuthal direction; (ii) the ratio of the variation in zenith distance to that in azimuth, and (iii) the ratio of the probable errors of the estimation of horizontal and vertical tangencies. We may omit the consideration of the last, and suppose that an investigation has shewn the first (i) to be κ, a quantity which is usually greater than unity and in some instruments amounts fully to 2. Then, for an observation for meridian, we should prefer

$$1 \text{ if } \frac{d\zeta}{dA} < \kappa, \text{ and } 2 \text{ if } \frac{d\zeta}{dA} > \kappa,$$

$d\zeta$ and dA denoting respectively the relative motions in zenith distance and azimuth. The reason of this is evident. In the former case it is necessary to measure the altitude with the greatest possible precision because of the large influence an error therein would have on the result. In the latter the error is less serious, and it is advantageous to bestow more attention upon the measurement of the azimuth. As before indicated, it is assumed that the defect in the estimation of the tangency is about the same for both instances, which is probably true in the case of observers

with normal eyes.[1] It is worthy of remark however that the precision of the estimation of tangency depends upon the direction of the apparent motion of the sun's image, being more perfect when the tangency is estimated at the last, than when at the first contact, *i.e.*, the advantage is for the positions illustrated in Fig. 4, when the apparent motions of the sun take place in the directions of the arrows. It is therefore desirable to secure when possible, similar conditions in morning and afternoon observations.

The following matters apply to any method of altazimuth solar observing, and are important :—

(i) The instrumental adjustments should be well made so that the outstanding corrections shall be small.

(ii) The level tubes upon which any corrections depend should never be allowed to remain partly in sun and partly in shadow, because under such circumstances the axis of the level, upon the constancy of which all confidence in its indications depends, changes. The value of the divisions of the level fluctuate, and are subject to some uncertainty even under the best attainable conditions.

(iii) The effect of the unequal heating of the metal which introduces sensible error in the larger instruments, should, as far as possible, be minimised by the scheme of the manipulation, that is by reversions, presentation of different sides to sources of heat, etc.

(iv) The effect of a very slight movement of rotation of the stand of the instrument, due to heating, warping etc., when instruments are not suitably protected by observing tents, should be eliminated by reading the direction of the 'referring object' both

[1] If there be any astigmatism this will not be true, and if the astigmatic defect be serious, it may greatly prejudice measurements in one position. Usually the vertical meridian of the cornea, at which the observer's optical system may be considered to commence, has a somewhat shorter radius of curvature and therefore a shorter focus, than the horizontal meridian. Observers who aim at a high degree of precision may not find it disadvantageous to test their vision for the measure of its astigmatic imperfection.

at the commencement and close of the observations. A similar procedure, in regard to the index error of the vertical circle, will reveal any change which may have taken place in the axis of the level attached to the alidade.

(v) Uncertainty in the assumed value of the latitude may be eliminated by combining observations symmetrically situated with respect to the meridian line, that is at equal intervals of time before and after *apparent* noon.

(vi) Even where it is intended to employ the method of equal altitudes, the observations should be so made as to permit of their reduction as altazimuth observations, because of the uncertainty of obtaining satisfactory observations on the other side of the meridian.

(vii) The barometric and thermometric readings should never be neglected, even for the method of equal altitudes, since the fore and after noon differences are usually quite appreciable. A difference of pressure of $+0{\cdot}1$ inch is equivalent to about $-1{\cdot}5^{\circ}$ Fahr., the amount of the refraction being increased by either change by $\frac{1}{30}$, or about $2''$ for an apparent altitude of 5°.

(viii) The advantage of securing a small azimuthal component in the sun's apparent motion by observing only at great zenith distances may be even more than abolished by the greater unsteadiness of the image near the horizon, and by the greater uncertainty in the absolute value of the refraction. In this connection it may be observed that the extraordinary variations of terrestrial refractions, and the systematic difference in the refractions across the sea and land, are a sufficient indication of the great uncertainty in the celestial refraction of rays nearly tangential to the earth's surface. Observations at a less altitude than say 10° should be made only under exceptional circumstances, especially when the azimuthal component of motion, compared with the vertical, is relatively large.

19. *The method of equal altitudes.*—If the directions of the sun's centre could be directly observed when at equal apparent

altitudes before and after noon, the mean of these would be to the east of the direction of the astronomical meridian[1] of the observer by the whole amount of the diurnal-aberration-correction for either position, provided the refraction and declination were identical for each position. From (21) § 7 it will be seen that the correction for diurnal aberration is very small, since A and ζ are generally not very far from 90°. If applied, however, the deduced meridian must be shifted *westerly*, because the mean direction would be either north-east or south-east, the former if the sun be observed when north-east and north-west, the latter when south-east and south-west.

The refraction is almost certain to be different at the two observations, because the barometric pressure and the temperature will have changed in the interval between them. The latter element should be measured in the same way for each, say by slowly whirling a thermometer in the air. The difference of refraction may be found with sufficient precision by multiplying the mean refraction for the zenith distance employed, by the differences of the products of the barometric and thermometric factors for the two pressures and temperatures recorded.

Let r denote the mean refraction, β and θ the correcting factors,[2] the suffixes indicating the observation to which they apply, then the difference of the refractions is

$$r_2 - r_1 = r\,(\beta_2\,\theta_2 - \beta_1\,\theta_1) \ldots\ldots\ldots\ldots\ldots (47)$$

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[1] Determined by the intersection with the horizon, of the vertical circle containing the pole of the heavens, and the observer's zenith, and subject therefore to the deflections due to the rugosity and heterogeneity of the earth's crust. This direction is of course quite distinct from the line perpendicular to the curve of the observer's latitude; this last may be called the "geodetic" meridian.

[2] For a table of mean refractions computed for 29·6 in. pressure at 32° Fahr. and 48·°75 Fahr. air temperature, the factors will be those in (n) § 6, or in (29) § 11. Bessel's refractions and correction factors pp. 430, 431, in Chamber's Mathematical Tables, 1885 Edit., may be used: the pressure and temperature of no correction is as before stated, those mentioned.

Not only will the difference of the refractions in the two observations involve the directions being determined for slightly different altitudes, the same consequence will also follow from the fact that the level and other corrections will not be the same; and further a satisfactory observation at the right moment will often fail to be made either from want of skill, from the presence of clouds, or from other causes. The difficulty in this respect may be obviated either by observing the altitude and azimuth both before and after the observation employed, and using the three results for the small interpolation from the middle one to the proper value of the altitude.[1] In this instance the observed values may be corrected *before* the application of the various corrections. Failing such additional observations the corrections must be made by spherical trigonometry.

Let Z P S denote respectively the zenith, the elevated pole, and the star in a celestial triangle, the parallactic angle q subtended by the colatitude, being at S. Then reckoning the azimuthal angle A from the elevated pole as positive either way the small azimuthal correction dA, for a small difference of zenith distance $d\zeta$, will be expressed by the formula

$$dA = -d\zeta \operatorname{cosec} \zeta \cot \left(q + \frac{dp}{dt \text{ arc } 1''}\right) \ldots\ldots (48)$$

dp denoting, with its proper sign, the variation of the polar distance in the time dt, both being expressed in arc. Dividing by arc $1''$ reduces the circular measure dp/dt to ordinary angular measure. The value of the small term to be added to q, can however never exceed $\frac{1}{9}\frac{1}{0}\,0$, or say $4'$, and may ordinarily be neglected, since the correction dA is itself very small.

Let ψ, p, A' and T' denote respectively the colatitude Z P, polar distance Z S at apparent noon on the day of observation, one half the azimuthal angle $S_1 Z S_2$ between the observed positions of the sun's centre, so taken as to include the elevated pole, and one half of the elapsed time $S_1 P S_2$ between the observations; then it will

[1] Three observations admit of a parabolic interpolation. If, however the correction is very small, two observations will be ample.

be usually quite accurate enough to calculate the parallactic angle q by either of the formulæ

$$\sin q = \frac{\sin \psi \sin A'}{\sin p} = \frac{\sin \psi \sin T'}{\sin \zeta} \quad \ldots\ldots\ldots(49)$$

though strictly the zenith and polar distances for the afternoon observation, together with the colatitude should be used to calculate that quantity; *i.e.* it should be determined from the three sides p_2, ζ_2, ψ_2.[1]

The equation of equal altitudes may be derived by writing the value of cos $(p \pm \frac{1}{2} dp)$—in which $\frac{1}{2} dp$ denotes the half difference between the polar distances at the two observations—in terms of ψ, ζ and A, and taking the difference of the results. This procedure gives

$$\sin \tfrac{1}{2} (A_2 - A_1) = \frac{\sin \frac{1}{2} dp \sin p}{\sin \psi \sin \zeta \sin \frac{1}{2} (A_2 + A_1)} \quad \ldots\ldots\ldots(50)$$

But the azimuth of the sun's centre is not directly observed, and the time must be recorded in order to compute the change of polar distance, hence, since

$$\sin A = \sin T \sin p \operatorname{cosec} \zeta$$

and the quantity (50) is small, the equation may with advantage be written in the simpler, approximate, but sufficiently accurate form

$$A_2 - A_1 = \frac{dp}{\cos \phi \sin T'}, \quad \ldots\ldots\ldots(50a)$$

ϕ the latitude being considered positive, and T' as before, half the elapsed time between the observations. The azimuthal angle A is reckoned east or west from the elevated pole. When the polar distance is increasing, the azimuthal angle from pole to sun is less for the first observation than for the second, whether the former be a morning or an afternoon observation.

For great precision, second differences should be taken into account in computing dp, especially at the solstices, being then considerable, although the change of declination is itself small.

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[1] We write ψ_2 because hereafter the case is considered where the second observation is made at a locality the latitude of which is slightly different.

At the equinoxes the change of declination is nearly 1′ per hour, but the second differences are negligible. The parallax, and augmentation with altitude, being the same for each observation may be entirely ignored.

It is sometimes inconvenient to occupy the same station for each observation, so that it is necessary to consider the case where the longitude and latitude are slightly different—a few minutes at most—for the two stations. These differences will be denoted respectively by $d\lambda$ and $d\phi$. It is easy to see that if the second station be nearer the pole than the first, *i.e.*, if $d\phi$ be +, the azimuthal angle measured from the elevated pole will be greater than it would be for a point of the same latitude. Hence we can correct the observed direction of the sun, so as to obtain that result which would have been given had an observation been made at a point on the meridian of the second station, on the parallel of latitude passing through the first.

If this *correction* be dA it will be given by the equation

$$dA = - d\phi \sec \phi \cot (T' \mp \tfrac{1}{2} \lambda) \ldots\ldots\ldots (51)$$

the minus sign in the last factor being used if the second station be west of the first. The $\frac{1}{2} \lambda$ term however is generally quite negligible. Now, if to the corrected direction, the correction for the declinational change be applied, the result will be that the deduced meridian will be $\frac{1}{2} (\lambda_1 + \lambda_2)$; *i.e.*, the direction of the meridian will have been determined for points whose longitude is the mean of the longitudes of the observing stations.

For the computation of the change of declination, the total elapsed time will of course be used, but in evaluating q by (49), we should strictly take

$$A' \mp \tfrac{1}{2} \nu \text{ and } T' \mp \tfrac{1}{2} \lambda,$$

ν being the convergency of the two meridians. The quantities $\frac{1}{2} \nu$ and $\frac{1}{2} \lambda$ are usually, however, so small as to be quite negligible in this relation.

In equal altitude observations we may observe either when the sun is in the positions marked 1 in Fig. 4, or when it is in the

positions marked 2; the criterion for determining this point being discussed in the preceding section, viz., § 18. In case 1, the line C D is supposed to be 'horizontal,' *i.e.* perpendicular to a vertical through I or J. Let the angle between the line C D and this perpendicular to the vertical, be ξ'' as in (45) § 16, and be regarded as positive when the D end droops. It is obvious that the tangent point observed will not be vertically above the sun's centre except when ξ'' is zero: therefore the values of X and Y in equation (45) must be taken into account as corrections to the results given immediately by observation. This may practically be avoided, at least in part, by observing in the manner indicated hereunder. In the suggested programme of observations, R O denotes the 'referring object,' that is an object on the line, the direction of which is to be ascertained; and N and R denote respectively the 'normal' and 'reversed' positions of the instrument, that is the position when the face of the vertical circle is to the right and when to the left, or *vice versa*.

Type 1.

Morning Observations.

Instrument N: read direction R O: put on dark glass:
N Alt. h': upper limb, read direction and time: reverse instr.
R „ h'': lower „ „ „ „ „ remove dark glass:
instr. being R re-read direction R O: take means.

Afternoon Observations.

Instrument R: read direction R O: put on dark glass:
R Alt. h'': lower limb, read direction and time: reverse instr.
N „ h': upper „ „ „ „ „ remove dark glass:
instr. being N re-read direction R O: take means.

If the temperature and pressure be nearly identical in the afternoon there will be no sensible correction for the error of altitude. If not let c' and c'' denote the contractions of the vertical diameter in the successive observations; and β and θ as before the refraction correction factors for barometer and thermometer, the suffixes 1 and 2 denoting morning and afternoon, respectively. Then, neglecting very small quantities, the *correction* for contractional

change between the observations, to be applied to the means of the observed *zenith distances*, will be respectively $-\frac{1}{2}(c_1' - c_1'')\cos\xi''$ and $-\frac{1}{2}(c_2' - c_2'')\cos\xi''$, see (45); that is to say these quantities must be *added*[1] to the mean of the observed zenith distances in order to obtain the mean of the zenith distances of the sun's centre for the same instants. In order therefore to make the afternoon corrected mean zenith distance the same as the morning one, we must *subtract* $d\zeta'$ say, derived from (45), and determined by the equation

$$d\zeta' = -\tfrac{1}{2}(c' - c'')\cos\xi''(\beta_2\theta_2 - \beta_1\theta_1).....(52)$$

the values of c being the tabular contractions, Table VII., § 11. Thus we may regard (52) as the *error* of the afternoon observation. The cosine term may be omitted since it is sensibly unity. The afternoon mean azimuthal reading will of course require to be corrected for the above error $d\zeta'$, see (48), which, since the afternoon temperature is generally considerably greater than the forenoon temperature, is usually *positive*.

The above contractional-variation-correction must not be confounded with the correction of the refraction, required when the mean of the observed zenith distances is employed, see Table III. § 6. Taking e from the table, the *error* of zenith distance in the afternoon will be

$$d\zeta'' = e(\beta_2\theta_2 - \beta_1\theta_1).....(53)$$

which is usually *negative*, and becomes zero if $h' = h''$.

The last error has the same sign as the absolute refraction correction, see (47), hence for observations of the *upper* and *lower* limbs of the sun, we may write for the total *error* $d\zeta$ of the zenith distance—other than instrumental—for which a correction must be applied to the mean of the second azimuthal readings, see (48).

$$d\zeta = [r - \tfrac{1}{2}(c' - c'') + e](\beta_2\theta_2 - \beta_1\theta_1).....(54)$$

It may be remarked that e must necessarily be very small if the observations are made in the manner indicated in the preceding programme.[2]

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1 That is with the sign attached: numerically they must be subtracted.

2 A practised observer will not require the time taken by the sun to move vertically through its diameter, 32′, before being ready for the second observation. It is well however, not to hurry the second morning observation, for the same rapidity in observing may not be realized in the afternoon.

The values of c' and c'' may be obtained from the table here under with sufficient exactness by adding half the semidiameter, or say 8′, to the observed *apparent* zenith distance when the upper limb is read, or by subtracting 8′ when the lower limb is read, for the argument with which to enter table. The quantities in the table, similarly to those in Table VII., require to be multiplied by the factor (29) § 11, that is by $\beta\,\theta$, but not when used in the formulæ immediately preceding.

TABLE IX.—*Vertical Contraction of the Sun's Semidiameter.*

$S_o = 16'$, Bar. 29·6, Therm. 48·75° Fahr.

Observed Zenith Distance, not corrected for refraction.

Zen. Distance	0°	15°	30°	40°	50°	55°	60°	65°	70°
Contraction	0″·23	0″·24	0″·32	0″·46	0″·63	0″·79	1″·04	1″·46	2″·23
Zen. Distance	75°	78°	80°	81°	82°	83°	84°	84½°	85°
Contraction	3″·81	5″·75	7″·98	9″·60	11″·79	14″·74	18″·84	21″·59	24″·99

In applying the corrections of (45) to the results of observations according to the preceding programme we have not yet taken account of the Y—or horizontal—correction. Rejecting the negligible quantities, the mean of the recorded azimuthal angles for the morning observations, measured from the elevated pole, requires the correction

$$-\tfrac{1}{2}\,S \sin \xi'' \,(\sec h'' - \sec h') + \tfrac{1}{2}\,(c' - c'') \sin \xi'' \sec h \ldots\ldots (x)$$

h denoting altitudes; and the mean of the afternoon observations require the same correction with the signs + and −. Hence we may correct only the afternoon azimuthal angle by adding thereto

$$dA' = S \sin \xi'' \,(\sec h'' - \sec h') - (c' - c'') \sin \xi'' \sec h \ldots (55)$$

h being the mean of the observed altitudes, and h' and h'' the approximate altitudes of the centre of the sun. The correction must necessarily be very small, hence $\beta\,\theta$ factors may be ignored.

The more usual method of making equal altitude observations is to record the direction and altitudes for the positions marked 2 in Fig. 4. When the lines A B or a b, the latter bisecting the angle E J F, are not vertical, the observation is not on a point defined by a vertical circle tangent to the side of the sun. In

this case therefore must be taken into account the values of X and Y in (46) § 16. The appropriate observing programme is as follows :—

Type 2.

Morning Observations.

Instrument N : read direction R O : put on dark glass :
N Alt. h' : leading limb, read direction and time : reverse instr.
R „ h'': following „ „ „ „ „ remove dark glass
instr. being N, re-read direction R O : take means.

Afternoon Observations.

Instrument R : read direction R O : put on dark glass :
R Alt. h'': leading limb, read direction and time : reverse instr.
N „ h' : following „ „ „ „ „ remove dark glass
instr. being N, re-read direction R O : take means.

The azimuths are subject to no correction, for even though the contractions differ in the afternoon, the differences cannot sensibly affect the azimuths.[1] If the vertical wire be supposed to be inclined the amount χ, similarly to F Q in Fig. 3, so that the upper part of the wire is to the right of the vertical, and the lower to the left, the correction to the mean of the *zenith distances* in the morning by (46) will be $-\sin\chi\,(c'-c'')\,\beta_1\theta_1$; and in the afternoon the same with the *opposite* sign, and with $\beta_2\theta_2$ in place of the last factor. Hence the total *error* $d\zeta'$ of the afternoon observation, in zenith distance, may be regarded, similarly to (52) in the preceding case, as

$$d\zeta' = (c'-c'')\sin\chi\,(\beta_1\theta_1+\beta_2\theta_2) \quad \ldots\ldots\ldots\ldots (56)$$

The whole term is so small that we may generally omit the $\beta\theta$ terms and write $\sin 2\chi$ as the factor instead of $2\sin\chi$.

The e term must be taken into account as in the preceding case, since we employ the mean of the zenith distances. The total *error*, for which an azimuthal correction is required, is consequently

$$d\zeta = d\zeta' + (r+e)\,(\beta_2\theta_2-\beta_1\theta_1) \quad \ldots\ldots\ldots\ldots (57)$$

---

1 That the contraction terms in (46) for Y cannot have any appreciable affect on the result may easily be verified. The terms $S\cos\chi\sec h'$ etc. cancel one another.

In both types of observing, the declinational change to be allowed for, will depend upon the difference between the means of the times of observation. This of course is not rigorously exact, but owing to the fact that the declinational change is slow and nearly uniform, that is the change is sensibly the same in the afternoon and forenoon, the error can never be appreciable.

The corrections to be applied to the mean altitude and mean azimuth by (12), (13) and (14) § 5 are not required, because they affect the forenoon and afternoon observations by the same amount.

Observations for equal altitude determinations of the meridian may also be made by the double tangency method, type 3 in Fig. 4. The programme would be generally similar to the preceding ones as regards normal and reversed positions and general manipulation. The following will sufficiently indicate it:—

Type 3.

Morning—1 Upper and leading limb; 2 Lower and following:
Afternoon—3 Lower and leading limb; 4 Upper and following.

The means would be taken throughout as in the preceding instances. Rejecting negligibly small quantities, it is evident from (39) and (*w*) § 14, that the mean of the zenith distances, both in the fore and afternoon, require a correction of the form

$$d\zeta' = -\tfrac{1}{2}(c' - c'')\beta\theta \cos\chi \operatorname{cosec}\gamma + \tfrac{1}{2}S^2 \cot z(\operatorname{cosec}\gamma - \cot\gamma)^2 \ldots(58)$$

But χ and γ, and $\beta\theta$ will not have the same values in the afternoon. For brevity let us put

$$G = \cos\chi \operatorname{cosec}\gamma, \text{ and } H = (\operatorname{cosec}\gamma - \cot\gamma)^2 \ldots(y)^1$$

then the correction in zenith distance to be applied when the whole correction it thrown into the afternoon observation, will be

$$d\zeta'' = -\tfrac{1}{2}(c' - c'')(G_2\beta_2\theta_2 - G_1\beta_1\theta_1) + \tfrac{1}{2}S^2 \cot z(H_2 - H_1) \ldots(59)$$

Obviously with properly adjusted diaphragm wires the final term would vanish, because the two values of H would be equal; and χ and γ being complementary the value of G would become unity.

---

[1] If γ be nearly 90°, the γ term will be very small. The expression may of course be written $\text{vers}^2\gamma/\sin^2\gamma$

With perfect adjustment in both cases this correction, viz. (59), therefore becomes exactly the same as (52).

These last three formulæ serve for the correction of observations of the type 3, see both the representations of Fig. 4.

20. *The method of altazimuths.*—The altazimuth method of solar observation has the advantage that each observation affords data by means of which the direction of the meridian can be deduced. Where the field of the telescope is sufficiently large, it is generally desirable to employ the double tangency method represented both in Fig. 3, and in observations of type 3 in Fig. 4; because this method yields accurate data both in respect of the altitude and azimuth at the moment of observation. If the direction of motion be sensibly vertical, however, the single tangency method type 2, Fig. 4, is to be preferred, because in that case a small error of altitude cannot sensibly influence the result, and the tangent point will be more perfectly determined than is possible when the two tangencies have to be simultaneously observed. The criterion for determining the selection of either method may be derived by a process analogus to that indicated in § 18 for the choice between observations of the type 1 and 2. The reduction of the results may be made by means of one or other of the formulæ (38) to (44) or (46) §§ 14, 15; so as to obtain the apparent direction and altitude of the sun's centre at the moment of observation. This altitude when corrected for refraction and parallax, the latitude of the point of observation, and the polar distance of the sun deduced from the recorded time at which the observation was made, are the data from which the azimuth or the hour angle of the sun's centre may be computed.

The influence of slight defects in the measurement of the positions of the diaphragm wires, of imperfect determinations of the collimation and level constants, and of rotational movements of the stand, may be minimised by taking a series of observations similar to those indicated in the preceding section, with similar reversions of the face of the vertical circle. Thus if the real

motion of the sun were that indicated by the arrows in 3 Fig. 4, the observations might be made thus :—

R O : IV, time alt. az. : reverse : II, time alt. az. : R O

and if four observations were desired, the continuation might with advantage be as follows :—

R O : I, time alt. az. : reverse : III, time alt. az. : R O.

The Roman figures denote the position in which the sun is to be observed, see the figure.

In the case of observations of a single tangency as 2 Fig. 4,[1] the opposite side of the sun would be observed in the second instance.

Reference has already been made, viz., in § 18, to the impossibility of employing the double tangency method with telescopes of high power, and to the fact that for good determinations of direction, the leading or following limb must perforce be observed, while for good values of the altitude the upper or lower limb must be taken whenever the azimuth component of the sun's motion is not extremely small as compared with its motion in altitude, it becomes necessary to ascertain with precision both elements for the same moment. Although this cannot be done directly it may be readily effected by using an electrochronograph. The routine of observation may be as follows, say for a morning observation :—

Observe (i.) upper limb and time : (ii.) leading limb and time :
(iii.) lower limb and time :

For a second observation, reverse face of instrument, and then

Observe (iv.) lower limb and time : (v.) following limb and time :
(vi.) upper limb and time.

By spherical geometry, and the theory of refraction and parallax, the altitude of the sun's centre for the moment of the leading or following limb observations, may be readily computed. In general there will be a slight discrepancy between the computed and observed differences of altitude between observations (i.) and (iii.), and (iv.) and (vi.) : the interpolated values of the altitude

[1] Or 1 for time : the motion being supposed to be nearly vertical.

for observations (ii.) and (v.) should of course be taken; that is to say, the altitude deduced from (iii.) should be allowed to influence the result as well as that from (i.), and the same in regard to (vi.) and (iv.)

It is perhaps hardly necessary to remark—see (v.) § 18—that, where there is any uncertainty in the latitude, observations should be taken if possible at equal intervals of time before and after apparent noon, especially if great precision be desired.

21. *Conditions of precision and general remarks.*—Owing to the great range of the sun's motion in declination, viz. about 47°, and the consequent change in the ratio between the azimuthal and vertical components for any given zenith distance, at different times in the year, the value of solar observations, for the determination of meridian, greatly varies. If the ratio of the components, *i.e.*, $dA/d\zeta$ be denoted by k, and the uncertainty of a measurement of the sun's altitude through instrumental and observational defects, together with the uncertainty of refraction, by $d\zeta$; then the whole uncertainty dA of the azimuth from these causes alone, will be

$$dA = k\, d\zeta \ldots\ldots\ldots\ldots\ldots\ldots (60)$$

Within the tropics k is never very large for great zenith distances, but for places outside it may in midwinter become considerable, so that it is not unimportant to estimate its value, when forming an opinion as to the reliableness of observations at any given time of the year. For example, when the sun has its maximum polar distance of about $113\frac{1}{2}°$, it crosses a vertical circle at an angle of 35°, not before its zenith distance is $80\frac{1}{2}°$ for latitude 35°, and not before that distance is $89\frac{1}{4}°$ for latitude 40°. The corresponding values of k are the cosecants of these angles, viz., 1·01 and unity, so that the uncertainty in azimuth is identical with that in altitude. Consequently even in latitude 35°, midwinter solar observations for meridian have not a high value as regards their accuracy.

The limiting values of latitude, at which observations made at a given zenith distance, will give a particular value of k for any

assumed polar distance, may be thus ascertained :—Let, as in § 4, I denote the angle of intersection between the direction of the sun's path and the vertical through its centre at any moment. Then similarly to (g) in that section, we have for the *parallactic angle* q, which is the complement of I,

$$\cot q = \tan I = \frac{dA}{d\zeta} \sin \zeta = k \sin \zeta \ldots\ldots\ldots\ldots (61)$$

After q is obtained, ϕ may be found for any value of p, by the following formulæ, in which θ is merely an auxiliary angle :—

$$\left.\begin{aligned} \tan \theta &= \tan \zeta \cos q \\ \sin \phi &= \frac{\cos \zeta \cos (p - \theta)}{\cos \theta} \end{aligned}\right\} \ldots\ldots\ldots (62)$$

If we make $\zeta = 80^\circ$, and k successively 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{3}$, the corresponding values of q will be 45° 26′, 53° 34′, 63° 47′ and 71° 50′. The curves shewn in Fig. 5 are obtained by (61) and (62) for that zenith distance ; the abscissæ being the polar distances measured from the elevated pole, and the ordinates the latitudes measured north or south from the equator. From the figure the latitude

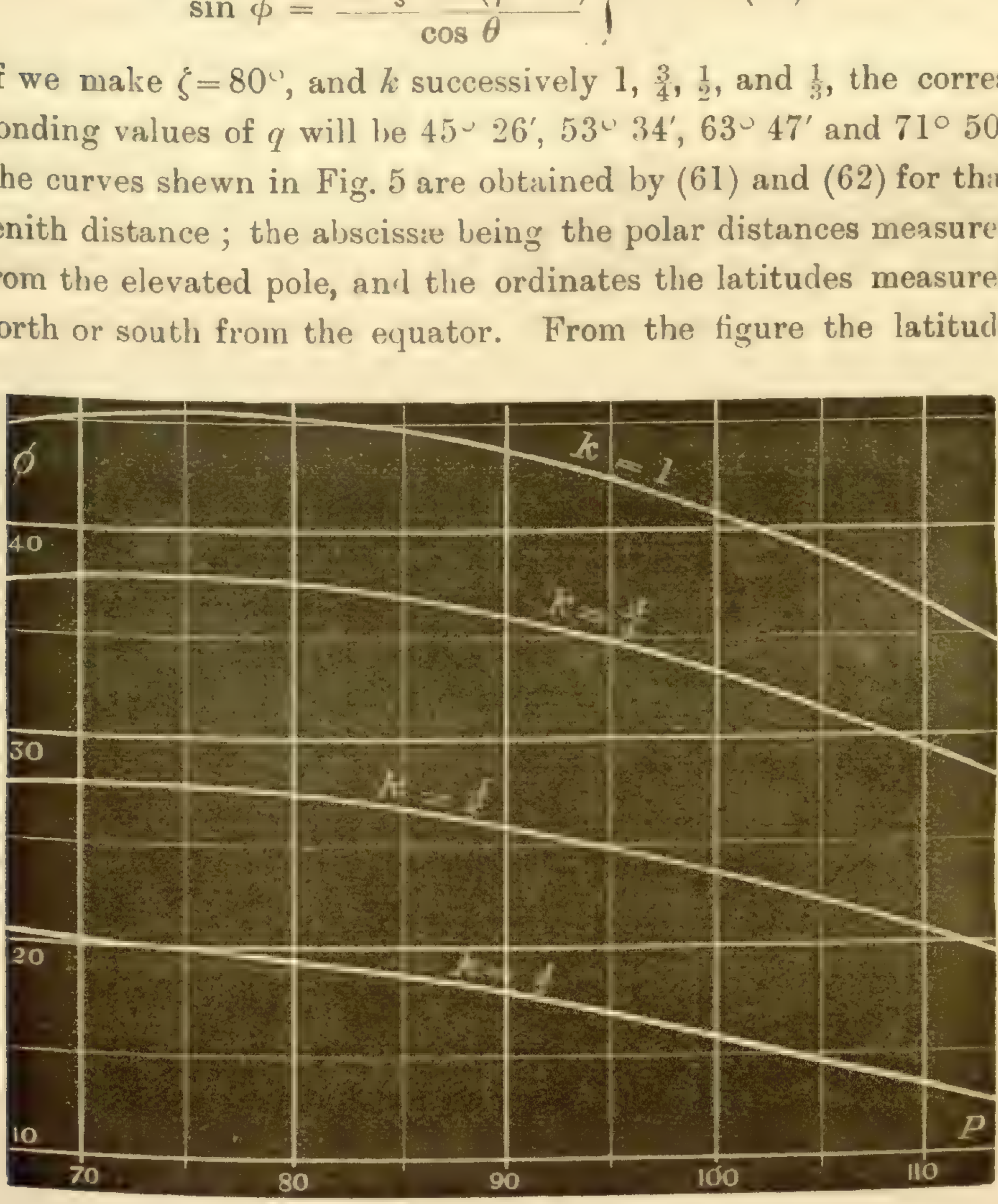

Fig. 5.

limits for any required ratio between the azimuthal and vertical components of motion, may be readily interpolated with sufficient precision for practical purposes. Very near the equator it will be desirable to observe the sun near its elongation rather than at a minimum altitude, if the altitude of elongation be not too great. It is of course never desirable to make observations for azimuth at great altitudes because level and collimation defects then enter into the result with large factors.

There is a source of persistent error in meridian determinations by solar observations, the amount of which cannot be accurately defined, but might perhaps be fairly well ascertained by a sufficient comparison with the results of stellar observations. This error, a consequence of the impossibility of obtaining complete data for the evaluation of refraction, and of the imperfection of the refraction theory, enters with a necessarily somewhat large factor into the results, and cannot be removed by combining morning and afternoon observations, because the physical conditions are asymmetrical. In the case of stellar observations the physical conditions for observations east and west of the meridian are frequently nearly symmetrical, and the final results consequently more reliable. The possibilities generally of meridian determination by solar observations have not, so far as I am aware, been fully investigated, and an exhaustive examination of this question is still a desideratum in geodesy. Where extreme precision is not required, the solar methods are very convenient, and involve but little loss of time. How far the application of more rigorous methods of reduction will be justified, can be ascertained only by a careful criticism of results: the uncertainties of refraction, and imperfections of definition are so serious that it is still a problem whether the results can be materially enhanced in value.

Re NOTABLE HAILSTORM of 17 NOVEMBER, 1896, in PARTS of PARISH of GORDON.

By E. Du Faur, F.R.G.S.

[With Plate XXIII.]

[*Read before the Royal Society of N.S. Wales, December 2, 1896.*]

Having submitted a short memorandum to the Government Astronomer, respecting this hailstorm, Mr. Russell asked me for further details, and suggested my preparing a paper on the subject to be read before our Society. I only propose to place before you this evening my notes, illustrated by a rough diagram of this phenomenal storm, considered by old residents to have been the severest one which has visited the district since that of 12th January, 1871, which is reported to have riddled most of the iron roofs in the locality, to have killed two horses, uprooted some of the heaviest timber, and to have been in all respects, but more especially in the force of the wind, more violent than the one now under consideration.

On our arrival at the Gordon Station at 5·21 p.m., on the evening in question, we found a considerable amount of hail lying on the platform, and heavy mist arising from the lands on the north-eastern side of the railway; before arriving at Pymble we found the lands on both sides of the line, completely white with hail; as white as after a moderately heavy winter snow-storm in Europe. Reaching Turramurra at 5·30 p.m., where I left the train, the hail, which had ceased falling some ten minutes previously, had almost half filled the empty trucks on the siding, and on the permanent way below the platform, sheltered apparently and not much subject to drift, the engine wheels had exposed the metals, but left a bank of hailstones on either side of them from ten to twelve inches high.

After a few words with the station master, and learning from my son that the fall had been only slight at my own place 'Pibrac,' about forty-five chains in a direct line, north-west by north from the station, I started to drive by the Eastern Road, due north, to ascertain the course of the storm. At a few chains from the railway gates the hailstones were lying over two feet deep against the eastern fence, and the ditch water had cut a tunnel through the deposit leaving for some yards an ice bridge over it. The owner of adjoining orchard, P. Gilroy, an old resident, had never seen anything like it, and would not readily believe my account of what I considered to have been a more severe one in Sydney some thirty years ago. I had gone but a few chains further north when all signs of severe hail ceased. On the first opportunity, at three-quarters of a mile from the station, I turned to east, and then north-east, along the "Kuring-gai Chase" road, and met with only slight signs of hail, while the ground to my right hand, at no great distance, still showed white with it through the timber; at one and three-quarter miles, an orchardist (King junr.) had had slight hail; and at three miles a road camp had none. Returning home I found there had been a severe rain storm with wind, but no hail of any consequence, rain gauge showing ·47.

During the next day I made full enquiries from fellow passengers, and on the Saturday I again drove round to further prosecute the same. From the press and private sources I learned that the storm had been very severe at Seven Hills and Baulkham Hills, and through the station master at Hornsby Junction I ascertained that its centre had crossed the Great Northern Railway near Carlingford, and that at Beecroft it had not been severe.

Accompanying tracing shows course from Seven Hills to Carlingford as almost west to east, (from W. 10° S. to E. 10° N.), with Baulkham Hills in line. From Carlingford to Turramurra, which undoubtedly received the fullest force of the storm, (or of a storm as will be further explained), the direct course is E. 52° N. or 42° to the north of course as determined above—from Seven Hills to Carlingford—: the intervening country, three miles fifty chains in

a direct line, is almost entirely uninhabited, through which runs the upper part of the Lane Cove River, three hundred feet below Carlingford and over five hundred feet below Turramurra.

In my conversation with the station master at Turramurra, who appears to have watched the storm with considerable care, he volunteered the information that it came from the south-west, but when it reached his station it seemed to go all ways: at first it was densest as it passed on the north-west side of his office, going north-east, with blue sky showing above it; then on the south-east of his office going east, again with blue sky above it; and I have little doubt that the further evidence which will be brought forward, will prove that at about this part the storm divided, one centre of intensity going a little to the north of north-east and probably blowing itself out, (or the hail turning to rain), in less than two miles; the other centre of intensity taking an easterly course of greater width. As to how far it extended, and at what point it crossed Middle Harbour Creek, whether as a hailstorm or rainstorm, I am not in a position to form any opinion, my tracing shows that at two miles east of Turramurra it was still very severe.

Returning now to Turramurra, my tracing locates the points of greatest intensity, on reliable evidence personally obtained, these being coloured pink and lettered.[1] After crossing Lane Cove Valley, and emerging from uninhabited lands, it first struck *A* and *B* (Herbert Cunningham and McCullock), virtually wrecking their gardens and destroying glass houses etc., at *G* (Adams) the hailstones were stated to be piled seven feet deep at the bottom of the paddock, and lying generally from one to two feet deep all over the property, but a few chains to the north-west of *A*, at *C* and *D*, (Elwyns and Blytheswood), it was much less severe, and at Langtree's at junction of Fox Ground road it was trifling. On the opposite side of the railway at *a* (Gerards) it was trifling; at *E*, *F* and *b*, (Coffee. Du Faur, and T. Reid), the same.

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[1] Places experiencing only slight or ordinary hail are shown by ⊙, and those were there was none by ○.

I have already shown its severe character at *H* (Gilroys); at *N* to *O*, (Vindin and others to Sulman's) it was even more so—gardens ploughed up, young trees destroyed, and at one house, (Capt. Bird's) about twenty roofing tiles and fifteen windows were smashed ; at *P* (Porter's orchard), *Q* (M. Bourke), *T* (Reilley) the fruit trees suffered very severely;[1] at *L* (Foster), within sight of the road along which I had driven immediately after the storm, and found it to be outside its limits, the hail lay three feet deep in some places, and the fruit crop—plums—was entirely destroyed, and trees injured to such an extent that Mrs. Foster considers herself ruined. As previously stated, the main storm extended no further in that north-east direction, only ordinary hail at King's, Reilley's, and King junr.—*c*, *d* and *e*—and none at all at *f* (Road Camp), and as there was also none at *h* (Phil. Richardson's), it can only have passed along a narrow strip of unoccupied country between those properties or have come to an end ; from my enquiries I am inclined to believe the latter alternative.

The orchards all through Irishtown generally suffered severely, but unequally; at *c* (S. King) no damage was sustained, but at *g* (Adams) the hail was very severe. I will return to this district later on.

Again starting from Turramurra, the land to the southward of the railway from *G* (Adams) to *R* (Cornwell) is mostly unoccupied; we had seen on the evening of the 17th at intervals between the cuttings, that it was all deeply covered with hail. At *R* (H. Cornwell) on the northern side of the railway, and at Mrs. Cornwell's on the southern, we again meet with evidence that they were subjected to the fullest force of the storm ; a large vineyard in full leaf, was stripped of three-fourths of its foliage, fruit trees not only suffered in loss of leaves and fruit, but their bark was split in all directions ; and all the windows in both houses exposed to the west were broken; the course of the storm here was unmistakeably from due west to east. At *S* (M. Porter) an orchard of

[1] At *T* the hail perforated corrugated iron.

large extent, great havoc took place; the owner stated that any one might have his apricot crop for £4, which he had valued half an hour previously at £400. Mr. Henry Cornwell, an old resident who has very greatly assisted me in my enquiries, subsequently went a considerable distance into the bush at the back of Mrs. Cornwell's and M. Porter's, and reports finding full evidence of the storm throughout. I have therefore tinted the whole of that country as having been under its severest influence. Continuing along the southern side of the railway, we find that at the church the hail was slight only, and at Mrs. Pockley's there was none; but at J. Brown's and Cook's orchards, on the opposite side, it was severe, the latter orchard is stated to be completely ruined; this defines the southern limit of the second division of the storm bearing almost due west and east as above mentioned.

As to its northern limit and its extension easterly, I am much indebted to Mr. C. B. Bradford, residing at *U* for information collected. Still excluding Irishtown for the present, the storm was at its height over all the space between the broken red lines on tracing, although I have only tinted those properties respecting which direct information was obtained. The country being very broken will probably account for effects not having been uniform, some properties suffered much more than others. At *U* (Bradford) the hailstorm was severe, but at *W* on the opposite side of the telegraph road and ridge it was worse, roofing slates being broken. It was specially severe at McKeown's, C. McIntosh's, Smart's, Connolley's, the small farms (Hughes and others), and at *x* W. Reid's former residence, where the roof tiles were broken; thence it entered the country leading down to Middle Harbour, which is unknown to us, and I believe but little occupied. This northern limit appears to be absolutely defined by the information that but slight hail fell at *i* (Etherington), and none as before mentioned at *h* (P. Richardson).

Returning to the question of the previous exclusion of the orchard district known as Irishtown, (which suffered very severely), from the limits of the greatest intensity of what I venture to

designate as the bifurcation of the main meteor, (coming from Seven Hills and Carlingford), into two currents, trending the one to the north-east, and the other due east: my reasons for this exclusion are as follows, viz.:—The evidence of the station master at Turramurra, to the effect of the storm having veered its course in all directions, has been further endorsed by others, and in Irishtown especially its favours appear to have been very unequally distributed; at *V* (Pymble jr.), as I am advised by Mr. Bradford, it at one time veered completely round to the east, *the hailstones having perforated the corrugated iron on a verandah facing easterly.* Mr. Bradford reports that Mr. Pymble junr., distinctly stated to him that, for a short time, he watched a flow of southerly wind, which appeared to beat back the storm and to divide it, the wind veering in all directions, with the results to his verandah above stated. This statement, as well as that of the station master at Turramurra, was volunteered to me, before I had formed any views of my own as to the bifurcation of the storm; in fact my first generalization of it, based on its effects at Turramurra only, as communicated in my memo. of the 18th to Mr. Russell, was that the storm appeared to have come from the south-west and to have travelled north-east.

I think that the evidence which I have illustrated on my diagram (*Plate* 23) proves indisputably the bifurcation referred to; that of Mrs. Foster and Adams, T. Porter and Reilley on the one hand, and of Brown, Cook, Hughes and W. Reid on the other, with the immunity of P. Richardson and S. King between the two, can scarcely admit of any other inference being drawn; and Pymble junr's. statement, backed by others, as to the veering of the wind in the central part about Irishtown, would appear to indicate a cycloidal disturbance much in the position in which it might have been expected to occur; but as to whether such disturbance was a cause or effect of the division of the main storm, is a matter on which I cannot pretend to offer an opinion.

Since completing the above notes, I have obtained some further information which appears to be of remarkable interest; to the

effect that the hailstorm was particularly severe after crossing the Lane Cover River, and caused ruinous havoc, at the few orchards about *Z* on the western side of the continuation of the Stony Creek road down to that river. This information, startling to me at first, would indicate that the bearing of E. 52° N., assigned above as the course of the centre of intensity of the storm, from Carlingford to Turramurra, was not a radical alteration of the course of the whole meteor, as at first supposed, but was due to its bifurcation at or near Carlingford; such disturbance in its course to be repeated again at or near Turramurra, as previously shown, and again at or near Swarze's to be seen hereafter; it is remarkable that at each of these points of bifurcation, the divided branches took approximately the same bearings, one to the north-east the other to the east.

The easterly branch from Carlingford devastated Swarze's strawberry farm at *y*, but did not extend to Pockley's *z*, nor Lindfield station; only a few scattered hailstones fell at Jenkin's orchard, therefore it must have expended itself between Swarze's and this part of the river; but a third departure to the north-east, or bifurcation, appears to have occurred near the river, as Mrs. Kendall's orchard at *Z* was almost ruined. It should be mentioned here that, with the exception of the three farms or orchards above mentioned, this part of the valley of Lane Cove River is virtually unoccupied, and information to be obtained is necessarily very meagre. After passing Mrs. Kendall's *Z*, the north-easterly branch must also have expended itself before reaching the Lane Cove Road; or following the main spur, by the river road, it may have joined the easterly branch from Turramurra, and increased its severity about J. Brown's and Cook's, (as it certainly did not extend to the Church, or Pockley's), and its junction with that branch may account for the various and shifting currents noticed by every one in its eastern part, and for the temporary southerly wind recorded by Pymble junr.

I trust that some of Mr. Russell's numerous correspondents will have enabled him to trace this meteor beyond the narrow

limits to which I have confined myself, both as to its initiation and final dispersion. I regret that the absence of my business partner, owing to a long illness, has left me little leisure for either more personal inspection or the putting together of available data in a better form. Had I not been so circumstanced I should have gladly given several of the days, immediately after the storm, to the personal collection of evidence in writing, from most of the residents and orchardists on its main lines ; and I think that the collation of such materials by more practised hands than mine, would have been very interesting, and possibly of some real value to meteorological research.

PROCEEDINGS

OF THE

ROYAL SOCIETY OF NEW SOUTH WALES.

WEDNESDAY, MAY 20, 1896.

ANNUAL GENERAL MEETING.

Prof. T. W. E. DAVID, B.A., F.G.S., President, in the Chair.

Fifty members and three visitors were present.

The minutes of the preceding meeting were read and confirmed.

The following Financial Statement for the year ending 31st March, 1896, was presented by the Hon. Treasurer, and adopted:—

GENERAL ACCOUNT.

RECEIPTS.		£	s.	d.	£	s.	d.
Subscriptions	One Guinea	130	4	0			
	Two Guineas	338	2	0			
	Arrears	17	17	0			
	Advances	1	1	0	487	4	0
Entrance Fees and Compositions					23	2	0
Parliamentary Grant on Subscriptions received during 1895					500	0	0
Sundries					7	6	11
Total Receipts					1017	12	11
Balance on 1st April, 1895					50	10	11
					£1068	3	10

PAYMENTS.	£	s.	d.	£	s.	d.
Advertisements	27	13	0			
Assistant Secretary	250	0	0			
Books and Periodicals	86	15	8			
Bookbinding	2	3	0			
Freight, Charges, Packing, &c....	20	16	6			
Furniture and Effects	14	18	6			
Gas	28	11	0			
Carried forward	£430	17	8			

PAYMENTS—*continued.*	£	s.	d.	£	s.	d.
Brought forward	430	17	8			
Housekeeper	7	10	0			
Insurance	10	1	6			
Office Boy	22	19	4			
Petty Cash Expenses	8	16	7			
Postage and Duty Stamps	32	15	0			
Printing	32	8	0			
Printing and Publishing Journal	326	18	6			
Prize Essay Award	25	0	0			
Rates	16	1	8			
Refreshments and attendance at Meetings ...	26	17	0			
Repairs	37	9	0			
Stationery	10	7	3			
Sundries	3	14	11			
Total Payments				991	16	5
Advance to Building and Investment Fund...				29	8	2
Balance on 31st March, 1896				46	19	3
				£1068	3	10

BUILDING AND INVESTMENT FUND.

RECEIPTS.

	£	s.	d.
Amount of Fund on 1st April, 1895	1286	0	1
Australasian Association for the Advancement of Science—			
First Instalment of Mortgage of £1,400	500	0	0
Advance from General Account	29	8	2
	£1815	8	3

PAYMENTS.

	£	s.	d.
Purchase of Land 14 ft. x 80 ft. 8 in.	1075	0	0
Survey and Plans of Land and Premises	7	7	0
Legal Expenses	35	2	4
Contractors on account of additions and alterations... ...	600	0	0
Architect	40	0	0
Rent of Temporary Office...	6	0	0
Rent of Cottage for Housekeeper	9	12	0
Nightwatchman	19	9	8
Labour, moving books and effects	9	0	2
Sundries	13	17	1
	£1815	8	3

CLARKE MEMORIAL FUND.

RECEIPTS.

	£	s.	d.
Interest on Fixed Deposit	8	7	0
Amount of Fund on 1st April, 1895	359	11	0
	£367	18	0

	£	s.	d.
Fixed Deposit in Government Savings Bank	183	7	1
Fixed Deposit in Savings Bank of New South Wales ...	184	10	11
	£367	18	0

ABERCROMBY FUND.

Receipts.	£	s.	d.
Amount received from the Hon. Ralph Abercromby to be offered as Prizes for Competitive Essays on various phases of Australian weather	100	0	0
Interest on Fixed Deposit, 1893	4	10	0
Interest on Fixed Deposit, 1894	4	13	7
Interest on Fixed Deposit, 1895...	2	7	7
	£111	11	2

Payments.	£	s.	d
Award for Prize Essay on "Southerly Bursters"	25	0	0
Illustrations for Ditto	16	3	9
Award for Prize Essay on "Types of Australian Weather,"	25	0	0
Illustrations for Ditto	14	0	0
Balance returned to the Committee	31	7	5
	£111	11	2

AUDITED, P. N. TREBECK.
H. O. WALKER.

SYDNEY, 23rd April, 1896.

H. G. A. WRIGHT, *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

Messrs. P. N. Trebeck and J. W. MacDonnell were appointed Scrutineers, and Mr. H. Deane deputed to preside at the Ballot Box.

A ballot was then taken and the following gentlemen were duly elected officers and members of Council for the current year:

Honorary President:

HIS EXCELLENCY THE RIGHT HON. HENRY ROBERT VISCOUNT HAMPDEN.

President:

J. H. MAIDEN, F.L.S.

Vice-Presidents:

CHARLES MOORE, F.L.S., F.Z.S. | PROF. THRELFALL, M.A.

PROF. ANDERSON STUART, M.D. | PROF. T. W. E. DAVID, B.A., F.G.S.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

J. W. GRIMSHAW, M. Inst. C.E. | G. H. KNIBBS, F.R.A.S., L.S.

Members of Council:

C. W. DARLEY, M. Inst. C.E.

HENRY DEANE, M.A., M. Inst. C.E.

W. H. GOODE, M.A., M.D.

W. M. HAMLET, F.C.S., F.I.C.

F. B. KYNGDON.

H. A. LENEHAN, F.R.A.S.

C. J. MARTIN, D. Sc., M.B.

E. F. PITTMAN, Assoc. R.S.M.

H. C. RUSSELL, B.A., C.M.G., F.R.S.

PROF. WARREN, M. Inst. C.E., Wh.Sc.

The certificate of one candidate was read for the second time, and of six for the first time.

The names of the Committee-men of the different Sections were announced :—

SECTION MEETINGS.

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ENGINEERING—Wednesday (8 p.m.)	14	17	15	19	16	21	18	16
MEDICAL—Friday, (8·15 p.m,)...		19	17		18		20	

NOTE.—The meeting of the Medical Section on June 19 will be held at the University.

SECTIONAL COMMITTEES—SESSION 1896.

Section H.—Medical.

Chairman—Dr. R. Scot Skirving.

Secretaries—Dr. C. J. Martin and Dr. J. A. Dick.

Committee—Dr. Cecil Purser, Dr. Alfred Shewen, Dr. W. H. Goode, M.A., Dr. G. E. Rennie, B.A.

Section K.—Engineering.

Chairman—Prof. Warren, M. Inst. C.E., Wh. Sc.

Secretary and Treasurer—T. H. Houghton, Assoc. M. Inst. C.E.

Committee—C. W. Darley, M. Inst. C.E., T. R. Firth, M. Inst. C.E., P. Allan, Assoc. M. Inst. C.E., C. O. Burge, M. Inst. C.E., D. M. Maitland, L.S., H. R. Carleton, M. Inst. C.E.

Past Chairmen, *ex officio* Members of Committee for three years: H. Deane, M.A., M. Inst. C.E., R. R. P. Hickson, M. Inst. C.E., and B. C. Simpson, M. Inst. C.E.

Meetings held on the Third Wednesday in each month, at 8 p.m.

Two hundred and thirty-one volumes, six hundred and twenty parts, one hundred and twenty-seven pamphlets, thirteen reports, five hydrographic charts, and twenty-two meteorological charts

received as donations since the last meeting were laid upon the table and acknowledged.

Due notice having been given at the previous meeting, it was unanimously resolved that the whole of the last paragraph of Rule XIV. be deleted, viz. :—

"At the meeting held in July, and at all subsequent meetings for the year, a list of the names of all those members who are in arrears with their annual subscriptions shall be suspended in the Rooms of the Society. Members shall in such cases be informed that their names have been thus posted.

Prof. T. W. E. DAVID, B.A., F.G.S., then read his address.

A vote of thanks was passed to the retiring President, and Mr. J. H. MAIDEN, F.L.S., was installed as President for the ensuing year.

Mr. MAIDEN thanked the members for the honour conferred upon him.

WEDNESDAY, JUNE 3, 1896.

J. H. MAIDEN, F.L.S., President, in the Chair.

Thirty-three members and five visitors were present.

The minutes of the previous meeting were read and confirmed.

The certificate of one new candidate was read for the third time and of six for the second time.

The following gentleman was duly elected an ordinary member of the Society :—

Cook, W. E., M.C.E. *Melb. Univ.*, M. Inst. C.E.; Pitt Street.

Sixteen volumes, sixty-three parts, two reports, and five pamphlets, received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "On periodicity of good and bad seasons," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

   Some remarks were made by the President, Prof. David, and Judge Docker

2. "The Mika operation of the Australian Aborigines," by Prof. T. P. ANDERSON STUART, M.D.
3. "The absorption of water by the gluten of different wheats," by F. B. GUTHRIE, F.C.S.

THURSDAY, JUNE 18, 1896.

A 'Reception' to the members of the Royal Society of New South Wales was held at the Society's House at 8 p.m., by way of commemorating the recent enlargements thereto.

The Hall and staircase were tastefully decorated with palms, ferns, and rare pot plants kindly supplied by Mr. J. H. Maiden, F.L.S., Director of the Botanic Gardens.

There were over three hundred guests present, including His Excellency the Governor (Honorary President of the Society) and Lady Hampden; about eight hundred invitations having been issued. The guests were received by the President (Mr. J. H. Maiden, F.L.S.), Professor Anderson Stuart, Professor Threlfall, Professor David (Vice-Presidents), Dr. Wright, (Hon. Treasurer), Mr. J. W. Grimshaw, and Mr. G. H. Knibbs (Hon. Secretaries), and Mr. C. W. Darley, Mr. F. B. Kyngdon, Mr. H. A. Lenehan, Dr. C. J. Martin, Mr. E. F. Pittman, Mr. H. C. Russell, C.M.G., and Professor Warren (Members of Council).

The Vice-Regal party arrived at 9 o'clock, and consisted of Lord Hampden, Lady Hampden, the Hon. Dorothy Brand, and Captain Ferguson, A.D.C. The other visitors included the Minister for Lands and the Minister for Justice.

EXHIBITS.

Brush Electrical Engineering Co., Ld.—Miner's Electric Lamps &c.

David, Prof.—Microscopes, specimens of Antarctic rocks obtained by Mr. Borchgrevink.

Dowling, J. P.—Queensland Cattle Tick (living specimens).

Government Geologist—Microscopic Slides.

Haswell, Prof.—A collection of zoological specimens showing various methods of mounting and displaying spirit specimens for Museum purposes.

Mann, J. F.—Plaster cast of Aboriginal body markings.

Public Library Trustees (per H. C. L. Anderson)—Collection of Rare Books including a very valuable edition of Shakespeare published in 1623 (preserved in an oak cabinet).

Public Works Department, Roads and Bridges Branch—Models of Bridges: Cowra, Mulwala, Wagga Wagga, and Lifting Bridge. Type of Truss 1886 and New Standard Type. Apparatus for recording deflection diagrams of Bridges.

Russell, H. C.—Lecturette and Lantern views, illustrating the developments of Stellar Photography.

Schofield, J. A.—Apparatus shewing the spectra of Argon and Helium.

Technical College, (per favor of Dr. Morris)—Miscellaneous Collection of models, electrical toys, and display of Geissler tubes.

Threlfall, Prof.—Extensive series of photographs by Röntgen's x rays.

Wilson, Prof.—Edinger's Drawing Apparatus by Leitz. Bernhard's Drawing Desk by Zeiss. New form of Abbe's Camera Lucida by Zeiss.

Wright, Dr.—Microscope and slides, photographs, a new Wellsbach lamp in which the vapour of methylated spirit was the illuminant.

WEDNESDAY, JULY 1, 1896.

J. H. MAIDEN, F.L.S., President, in the Chair.

Forty-three members and nine visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of six candidates were read for the third time, and of five for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Elwell, Paul Bedford, M.I.C.E., M.I.E.E. ; Sydney.
Onslow, Major J. W. Macarthur ; Camden Park.
Merfield, Charles J., F.R.A.S. ; Marrickville.
Smyth, Selwood ; Harbours and Rivers Branch.
Spencer, Walter, M.D. *Brux.;* Enmore.
Thompson, Capt. A. J. Onslow ; Camden Park.

The President announced that a Building Fund had been started to which Dr. F. H. Quaife had generously donated £20.

Twenty-two volumes, one hundred and nine parts, twenty reports and twenty-one pamphlets received as donations since the last meeting were laid upon the table and acknowledged.

A discussion took place on the paper read by Mr. H. C. Russell at the previous meeting, "On periodicity of good and bad seasons," in which the following gentlemen took part, viz.:—Prof. Gurney, Messrs. D. M. Maitland and P. N. Trebeck, Prof. Threlfall, Mr. Carment, Prof. David, Mr. Henry Deane and the President.

Mr. Russell replied.

Prof. THRELFALL read some "Notes on recent developments of Röntgen Rays," and exhibited some of the latest forms of tubes used.

WEDNESDAY, AUGUST 5, 1896.

J. H. MAIDEN, F.L.S., President, in the Chair.

Thirty-eight members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of five new candidates were read for the second time, and of five for the first time.

Twenty volumes, one hundred and eighteen parts, four reports and five pamphlets received as donations since the last meeting were laid upon the table and acknowledged.

The following papers were read :—

1. "On the occurrence of a submerged forest with remains of the dugong at Shea's Creek," by R. ETHERIDGE, Junr., Professor T. W. E. DAVID, B.A., F.G.S., and J. W. GRIMSHAW, M. Inst. C.E.

   The paper was read by Prof. David, and some remarks made by Messrs. E. F. Pittman, H. Deane, and R. Etheridge.

2. "On Aromadendrin or Aromadendric Acid from the Turbid Group of Eucalyptus Kinos, by HENRY G. SMITH, F.C.S.

   Some remarks were made by the Chairman.

3. "On the Cellular Kite," by LAWRENCE HARGRAVE.

Remarks were made by Professors Threlfall and Warren, and the author.

4. "An explanation of the marked difference in the effects produced by subcutaneous and intravenous injection of the venom of Australian snakes," by C. J. MARTIN, M.B., D.Sc.

5. "Note on a method of rapidly separating crystalloids from colloids by filtration," by C. J. MARTIN, M.B., D.Sc.

EXHIBITS:

Mr. HENRY G. SMITH exhibited a specimen of Lepidolite (Lithia mica) from near Norseman, West Australia. This specimen of lepidolite was found six miles south of Norseman near Dundas, Western Australia. Norseman was named by a Mr. Sinclair, who came from the north isles of Scotland and who found the first mine there (the Norseman Reward). It is one hundred and forty-four miles north of Esperance Bay and one hundred and twenty-five miles south of Coolgardie. It is situated in the Dundas gold-field. I am indebted to Mr. M. E. Fennessy for the specimen and the information. Lepidolite is one of the substances from which the lithia salts of commerce are obtained; it also usually contains the rare elements cæsium and rubidium. It is far from being a common mineral; in Australia it is of rare occurrence. Professor Liversidge states that it "is reported by Ranft to occur at Black Swamp, Mole Tableland, New England." I am expecting shortly to receive more material when an analysis will be made and submitted to the Society.

WEDNESDAY, SEPTEMBER 2, 1896.

Mr. J. H. MAIDEN, F.L.S., President, in the Chair.

Thirty-two members and six visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of five candidates were read for the third time, of five for the second time, and of three for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Barff, A. E., M.A.; Sydney University.
Edwards, George Rixon ; Coonamble.
Gollin, Walter J. ; Darling Point.
Pope, Rowland James, M.D., C.M., F.R.C.S. *Edin.*; Sydney.
Thom, John Stuart ; Bexley.

Twenty-five volumes, one hundred and forty-six parts, seven reports and six pamphlets received as donations since the last meeting, were laid upon the table and acknowledged.

The following papers were read :—

1. "Note on recent determinations of the viscosity of water by the efflux method," by G. H. KNIBBS, F.R.A.S., L.S.

Some remarks were made by Mr. J. A. Pollock.

2. "Current Papers No. 2," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

Some remarks were made by Prof. David.

EXHIBITS.

I.—(1) Specimens of steel rails which had been subjected to chemical analysis and etched, so as to show the variations in structure.

(2) A new and simple style of funnel holder, etc.

(3) A new kind of pipette for ensuring the accurate dropping of liquids, were exhibited by Mr. W. M. HAMLET.

A discussion followed in which the following gentlemen took part, viz. :—Major McCutcheon, Prof. David, Messrs. G. H. Knibbs, H. Deane, and the President, to which Mr. Hamlet replied.

II.—Cloud photograph transparencies, showing seven different and typical forms were exhibited by Mr. RUSSELL.

III.—Several exhibits from the Physical Laboratory of the Sydney University were shown by Mr. J. A. POLLOCK on behalf of Prof. THRELFALL and himself.

IV.—A case of valuable cut and uncut gems from the Department of Mines was exhibited by Mr. E. F. PITTMAN.

V.—A collection of gem stones from the Kangaloon Mines, Nepean River, was exhibited by Mr. H. E. SOUTHEY, Mittagong.

VI.—(1) Micrographic slides and specimens of columnar and Cretaceous ? gabbro from the great sill of the Derwent estuary, Tasmania.

(2) Micrographic slides and specimens of Pre-Cambrian Oolitic limestone from Halletts' Cove near Adelaide, were exhibited by Prof. T. W. E. DAVID.

VII.—Mr. C. HEDLEY exhibited a quantity of 'Kava' root (from the Ellice Group) which he ground and prepared for those who might wish to taste it.

WEDNESDAY, OCTOBER, 7, 1896.

J. H. MAIDEN, F.L.S., President, in the Chair.

Thirty-six members and seven visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of five new candidates were read for the third time, of three for the second time, and of ten for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Archer, Samuel, B.E., Roy Univ. *Irel.*; Mudgee.

Bridge, John ; Circular Quay.

Hinder, Henry Critchley, M.B., C.M. *Syd.*; Ashfield.

Ruse, Byron ; Ashfield.

Walsh, C. R. ; Supreme Court.

The President announced that the Society's Bronze Medal and prize of £25 had been awarded to the Rev. J. Milne Curran for paper on "The occurrence of precious stones in New South Wales, with a description of the deposits in which they are found."

Seventeen volumes, one hundred and thirty-six parts, seven reports, nine pamphlets, ten hydrographic charts and sixteen

meteorological charts received as donations since the last meeting were laid on the table and acknowledged.

The following papers were read :—

1. "On the occurrence of precious stones in New South Wales, with a description of the deposits in which they are found," by the Rev. J. MILNE CURRAN.

2. "On the constituents of the sap of the 'Silky Oak,' *Grevillea robusta*, R.Br.," by HENRY G. SMITH, F.C.S.

Some remarks were made by Mr. Hamlet and the President.

WEDNESDAY, NOVEMBER 4, 1896.

J. H. MAIDEN, F.L.S., President, in the Chair.

Twenty-seven members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of three new candidates were read for the third time, of ten for the second time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Fairfax, Geoffrey E. ; Sydney.
Verdon, Arthur ; Australian Club.
Vivian, Walter Hussey ; Manly.

The President announced the death of Baron Ferdinand von Mueller, K.C M.G., F.R.S., who was elected an Honorary Member of the Society in 1875, and awarded the Clarke Medal in 1883.

He then presented to the Rev. J. Milne Curran the Society's Bronze Medal and money prize of £25, which had been awarded to him for paper on "The occurrence of precious stones in New South Wales, with a description of the deposits where they are found."

Twenty-four volumes, one hundred and five parts, two reports, six pamphlets, two hydrographic charts and two engravings received as donations since the last meeting were laid on the table and acknowledged.

The following paper was read :—

"On sill structure and occurrence of fossils in eruptive rocks in New South Wales," by Prof. T. W. E. DAVID, B.A., F.G.S.

Some remarks were made by the Rev. J. Milne Curran and the author.

The paper on "The occurrence of precious stones in New South Wales etc., by the Rev. J. Milne Curran, which had been read at the previous meeting, was then discussed, the following gentlemen taking part :—Mr. Henry G. Smith, Prof. David, and the President ; the author replied.

WEDNESDAY, DECEMBER 2, 1896.

J. H. MAIDEN, F.L.S., President, in the Chair.

Thirty members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of ten new candidates were read for the third time, of two for the second time, and of three for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

à Beckett, Marsham Elwin ; Ashfield.

Brown, Alexander ; Newcastle.

Deas-Thomson, E. R.; Elizabeth Bay Road.

Fairfax, Charles Burton ; Sydney.

Gibson, Frederick William D. C. J. ; Stanmore Road.

Hay, Alexander ; Australian Club.

King, Kelso ; Darling Point.

Smith, Thomas Hawkins ; Gordon Brook, Clarence River.

Thom, James Campbell ; Bexley.

Tickle, A. H.; Woollahra.

On the motion of Mr. HENRY DEANE seconded by Mr. J. T. WILSHIRE, it was resolved that Messrs. H. O. WALKER and C. R. WALSH be appointed Auditors for the current year.

Eighteen volumes, one hundred and eight parts, four reports and three pamphlets received as donations since the last meeting were laid upon the table and acknowledged.

A letter was read from the Victorian Branch of the Royal Geographical Society of Australasia together with the report of a special meeting of the Branch held November 2nd, *re* proposed Memorial to the late Baron Ferdinand von Mueller, K.C.M.G., F.R.S.

The following papers were read :—

1. "On the presence of a true manna on a blue-grass, *Andropogon annulatus*, Forsk." by R. T. BAKER, F.L.S., and HENRY G. SMITH, F.C.S.

   Remarks were made by Messrs. G. H. Knibbs, J. T. Wilshire, and the President, to which the authors replied.

2. "Remarkable hailstorm of 17 November, 1896 in parts of Parish of Gordon" by E. DU FAUR, F.R.G.S.

   Some remarks were made by Mr. H. C. Russell.

3. "On the determination of the "Meridian Line by Solar observations with any altazimuth-instrument," by G. H. Knibbs, F.R.A.S., L.S.

Mr. GRIMSHAW exhibited a silicious tube-like material probably a fulgurite, found on the sand-hills Kensington.

PROCEEDINGS OF THE SECTIONS

(IN ABSTRACT.)

ENGINEERING SECTION.

At the provisional meeting held 14th May, the following officers were elected for the 1896 Session:—Chairman: Professor WARREN, M. Inst. C.E., Wh.Sc. Hon. Secretary and Hon. Treasurer: T. H. HOUGHTON, Assoc. M. Inst. C.E. Committee: C. W. DARLEY, M. Inst. C.E., T. R. FIRTH, M. Inst. C.E., P. ALLAN, Assoc. M. Inst. C.E., C. O. BURGE, M. Inst. C.E., D. M. MAITLAND, L.S., H. R. CARLETON, M. Inst. C.E.

The *ex officio* members of the Committee being H. DEANE, M. A. M. Inst. C.E., R. R. P. HICKSON, M. Inst. C.E., and B. C. SIMPSON, M. Inst. C.E.

The Hon. Treasurer presented the balance sheet of the printing fund for 1895, shewing a credit of 19s. 6d. Messrs. HAYCROFT and COWDERY were elected auditors.

Monthly meeting held June 17.

Professor WARREN, in the Chair.

Thirty-two members and visitors present.

The Chairman notified that through illness Mr. Houghton had been compelled to resign the positions of Hon. Secretary and Hon. Treasurer, and that Mr. Percy Allan had been appointed Hon. Secretary and Hon. Treasurer.

The Chairman then delivered his presidental address.

Monthly meeting held July 15.

Professor WARREN in the Chair.

Nineteen members and visitors present.

A vote of congratulation was accorded to Mr. Deane on his appointment to the Council of the Institution of Civil Engineers.

Mr. SELFE read a paper on "the Machinery Employed for Artificial Refrigerating and Ice Making," and the discussion was adjourned to the next meeting.

Monthly meeting held August 19.

Mr. C. O. BURGE in the Chair.

Thirty-two members and visitors present.

Mr. MCKINNEY read a paper on the "Water Conservation Surveys for New South Wales," and the discussion was adjourned to the next meeting.

The discussion on Mr. NORMAN SELFE'S paper on "the Machinery Employed for Artificial Refrigerating and Ice Making," was opened by Mr. Cruickshank and continued by Messrs. Stayton, Eaton, Houghton, and Stokes, and adjourned to the next meeting.

Monthly meeting held 16 September.

Professor WARREN in the Chair.

Fourteen members and visitors present.

The discussion on Mr. NORMAN SELFE'S paper on "the Machinery Employed for Artificial Refrigerating and Ice Making," adjourned from last meeting was continued by Professor Warren and replied to by the author.

The discussion on Mr. MCKINNEY'S paper on the "Water Conservation Surveys of New South Wales," was opened by Mr. Halligan and continued by Messrs. Haycroft and Davis, and adjourned to the next meeting.

Monthly meeting held October 21.

Professor WARREN in the Chair.

Twenty-six members and visitors present.

Mr. A. B. PORTUS read a paper on "Centrifugal Pump Dredging in New South Wales," the discussion was opened by Mr. C. W. Darley and continued by Mr. Grimshaw, further discussion being adjourned till the next meeting.

The discussion on Mr. MCKINNEY'S paper on the "Water Conservation Surveys of New South Wales," adjourned from the

previous meeting was continued by Messrs. C. W. Darley and Merfield, and replied to by the author.

Pleasure was expressed at the presence of Colonel Home and Mr. Mais.

Monthly meeting held November 18.

Professor WARREN in the Chair.

Twenty-four members and visitors present.

Mr. PERCY ALLAN read a paper on the "Lift Bridge over the Murray River at Swan Hill," the discussion being adjourned till the next meeting.

The discussion on Mr. A. B. PORTUS paper on "Centrifugal Pump Dredging in New South Wales," adjourned from the previous meeting was continued by Professor Warren and Mr. Percy Allan and adjourned till the next meeting.

Mr. BARRACLOUGH read a paper on the "Experimental Theory of the Steam Engine," the discussion being adjourned till the next meeting.

Monthly meeting held December 16.

Professor WARREN in the Chair.

Twelve members and visitors present.

The discussion on Mr. A. B. PORTUS paper on "Centrifugal Pump Dredging in New South Wales," adjourned from the previous meeting was continued by Messrs. Houghton, Haycroft, Barraclough, and Grimshaw, and replied to by the author.

The discussion on Mr. PERCY ALLAN'S paper on the "Lift Bridge over the Murray River at Swan Hill," was opened by Mr. Burge and continued by Messrs. Haycroft, Grimshaw, Dare, and Professor Warren, and replied to by the author.

The discussion on Mr. BARRACLOUGH'S paper on the "Experimental Theory of the Steam Engine," was opened by Mr. Houghton and replied to by the author.

The Chairman briefly referred to the work of the past session.

During the Session the Section visited, by invitation, the Sewerage Works at Johnstone's Creek, Annandale, and the Sand Pump Dredges working at Rozelle Bay.

Mr. W. THOW was on the 11th November elected to the vacancy on the Committee caused by the resignation of Mr. Maitland.

MEDICAL SECTION.

The first meeting of the Session was held in the Basement Hall of the Society's House, on May 15th, 1896, at 8·15 p.m., when the following officers were elected:—Chairman: Dr. ROBERT SCOT SKIRVING. Committee (4): Drs. W. H. GOODE, A. SHEWEN, C. PURSER, G. E. RENNIE. Hon. Secretaries: Drs. C. J. MARTIN, J. A. DICK.

The dates of the meetings of the Section were fixed.

Dr. F. MILFORD read a paper on "Some experiences of Skull and Head injuries with their results during a lengthy practice in Sydney."[1]

SPECIAL GENERAL MEETING.

A Special General Meeting of the Section was held in the Physics Lecture Room of the University of Sydney (by kind permission of the Senate) on June 19th at 8·15 p.m. Dr. SCOT SKIRVING occupied the Chair, there was a very large attendance of members of the Society and their friends.

Professor THRELFALL, M.A, gave a Lecture-Demonstration upon "The 'x' rays of Röntgen and their practical application."[2]

FIRST ORDINARY BI-MONTHLY MEETING.

The first ordinary Bi-monthly meeting of the Section was held in the Hall of the Society's House, on July the 17th at 8·15 p.m. Dr. SCOT SKIRVING in the Chair.

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[1] Australasian Medical Gazette for 1896, p. 294.

[2] A.M.G., 1896, p. 294. Hermes Medical Supplement for May, 1896.

Dr. S. T. KNAGGS read a paper upon "Human Fallibility and its relation to Accidents on Railways and by Sea."[1]

The subject was discussed by Drs. F. Norton Manning, Sydney Jones, C. J. Martin, Joseph Foreman, and others.[2]

Dr. F. TIDSWELL exhibited a series of micro-photographs and microscope preparations illustrating the Histo-pathology of Leprosy.[3]

Dr. TIDSWELL also exhibited some specimens of the Queensland cattle ticks.[3]

Drs. C. J. Martin and J. A. Dick discussed the micro-photographs.

Recent additions to the University Museum of Normal and Morbid Anatomy were exhibited by the Curator, Dr. S. JAMIESON.[4]

SECOND ORDINARY BI-MONTHLY MEETING.

The Second Ordinary Bi-monthly meeting was held in the Hall of the Society's House on September 18th at 8·15 p.m. Dr. SCOT SKIRVING in the chair.

Dr. CLUBBE exhibited a patient who had suffered from extensive fracture of the skull with subsequent considerable loss of cerebral tissue.[5]

Dr. MACDONALD GILL (at the invitation of the Hon. Secretaries) exhibited an infant who was suffering from annulus migrans of the tongue.[6]

Dr. F. W. HALL (at the invitation of the Hon. Secretaries) exhibited an adult who was suffering from scleroderma, also an infant the subject of cretinism.[6]

The patients were examined by the members, after which their cases were discussed.

Dr. JENKINS exhibited a spirit specimen of malignant disease of the stomach.[6]

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[1] A.M.G., p. 359. [2] A.M.G., p. 362.
[3] A.M.G., p. 346. [4] A.M.G., p. 347.
[5] Hermes Medical Supplement for November 1896; A.M.G., p. 443.
[6] A.M.G., p. 444.

Dr. FJELDSTAD (at the invitation of the Hon. Secretaries) demonstrated the application of the Norwegian Venetian-blind splint.[1]

Dr. MULLINS demonstrated the structure of three varieties of filters for drinking-water.[2]

Dr. SYDNEY JONES described some skiagraphs from a case of Leprosy that were on view.[2]

Dr. WM. CHISHOLM described some skiagraphs of elbow joint injuries that were on view.[2]

Recent additions to the University Museum of Normal and Morbid Anatomy were exhibited by Dr. JAMIESON.[2]

Various patterns of Pasteur-Chamberland, Berkefeld, and Jeffrey filters were exhibited by the Hon. Secretaries.[2]

Several skiagraphs of medical and surgical interest, taken by Mr. F. SCHMIDLIN were exhibited by the Hon. Secretaries.[2]

The other business was postponed.

THIRD ORDINARY BI-MONTHLY MEETING.

The Third Ordinary Bi-monthly meeting was held in the Hall of the Society's House on November 20th. Dr. W. H. GOODE presided in the absence of Dr. SCOT SKIRVING who sent an apology.

Dr. J. A. DICK exhibited a case of partial cryptorchismus.

Dr. S. JAMIESON read a paper on "Osteitis Deformans" and exhibited several specimens.[3]

The subject was discussed by Drs. Rennie, Martin, Goode and others.[4]

Drs. C. J. MARTIN and G. E. RENNIE read a joint paper upon 'Cardiac Thrombosis.'

The paper was discussed by Professor J. T. Wilson, Drs. Sydney Jones, Wm. Chisholm, S. Jamieson, W. H. Goode and others.[4]

The acting Chairman announced that this was the last meeting of the Session.

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[1] A.M.G., p, 469. [2] A.M.G., p. 444.
[3] A.M.G., Jany. 1897, p. 14. [4] A.M.G., p. 531.

ADDITIONS

TO THE

LIBRARY OF THE ROYAL SOCIETY OF NEW SOUTH WALES.

DONATIONS—1896.

(The Names of the Donors are in *Italics.*)

TRANSACTIONS, JOURNALS, REPORTS, &c.

AACHEN—Meteorologische Station I. Ordnung. Deutsches Meteorologisches Jahrbuch für 1895. *The Director*

ABERDEEN—University. Calendar for the year 1896-97. Catalogue of Books added to the Library in King's College, March 1894 to March 1895. *The University*

ADELAIDE—Observatory. Meteorological Observations during 1891, 1892, and 1893. *The Observatory*

Royal Society of South Australia. Transactions, Vol. XVI., Part iii., 1896; Vol. XIX., Part ii., 1895; Vol. XX., Part i., 1896. *The Society*

ALBANY—University of the State of New York. Bulletin of the New York State Museum, Vol. III., Nos. 14, 15, 1895. State Library Bulletin, Legislation No.6, 1895. *The University*

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ANNAPOLIS, Md.—U.S. Naval Institute. Proceedings, Vol. XXI., Nos. 3, 4, Whole Nos. 75, 76, 1895; Vol. XXII., Nos. 1, 2, Whole Nos. 77, 78, 1896. *The Institute*

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BALTIMORE—Johns Hopkins University. American Chemical Journal, Vol. XVI., Nos. 7, 8, 1894; Vol. XVII., Nos. 1 – 10, 1895; Vol. XVIII., 1 – 5, 1896. American Journal of Mathematics, Vol. XVI., No. 4, 1894; Vol. XVII., Nos. 1 – 4, 1895; Vol. XVIII., Nos. 1, 2, 1896. American Journal of Philology, Vol. XV., Nos. 2 – 4, 1894; Vol. XVI., No. 1, 1895. Circulars, Vol. XV., Nos. 121 – 126, 1895-96. Historical and Political Studies, Vol. XII., Nos. 8 – 12, 1894; Vol. XIII., Nos. 1 – 12, 1895; Vol. XIV., Nos. 1 – 5 1896. *The University*

BATAVIA—Koninklijke Natuurkundige Vereeniging in Nederl-Indië. Natuurkundig Tijdschrift voor Ned.-Indië, Deel LV., (Negende Serie Deel IV.) 1896. Supplement-Catalogus der Bibliotheek (1883-1893) Boekwerken, 1895.
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Königlich Preussische Akademie der Wissenschaften. Sitzungsberichte, Nos. 39 - 53, 1895; Nos. 1 - 39, 1896. *The Academy*

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BERNE—Département de l'Interieur de la Confédération Suisse —Section des Travaux Publics. Bassin du Rhin depuis ses sources jusqu à l' embouchure de la Tamina, Parts 1 and 2; Rheingebiet von den quellen bis zur Taminamündung, Theil 1 and 2, 1896. Graphische Darstellung der Schweizerischen hydrometrischen Beobachtungen, Pl. I. - XVI., 1895. Graphische Darstellung der Lufttemperaturen Pl. 1, 2, 3, 1894. Tableau graphique des observations hydrométriques Suisses, Pl. I. - XVI., 1895.
The Department

BIRMINGHAM—Birmingham and Midland Institute. Report of the Council for the year 1895. "The Use of Life" by Rt. Rev. W. B. Curpenter, D.D., delivered in the Town Hall, Birmingham, 22 Oct. 1895. Programme for Session 1896-97. *The Institute*

Birmingham Natural History and Philosophical Society. Proceedings, Vol. IX., Part ii., 1895. *The Society*

BISTRITZ—Ecole Industrielle. Jahresbericht der Gewerbeschule. XX. and XXI., 1894-96. *The School*

BONN—Naturhistorische Vereins der Preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück. Verhandlungen, Jahrgang LII., 1895. *The Society*

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BREMEN—Meteorologische Observatorium. Ergebnisse der Meteorologischen Beobachtungen im Jahre 1895, Jahrgang VI. *The Director*

Naturwissenschaftliche Verein. Abhandlungen, Band XIII., Heft 3, 1896; Band XIV., Heft 1, 1895. *The Society*

BRISBANE—Australasian Association for the Advancement of Science. Report of the Sixth Meeting held at Brisbane, Queensland, Jan , 1895. *The Association*

Chief Weather Bureau. Meteorological Synopsis, May – Dec. 1895, Jan. – April 1896. Climatological Tables, Jan. – Dec. 1895. Table of Rainfall, Jan. – Dec. 1895. *The Bureau*

Department of Agriculture. Botany Bulletin, No. 13, 1896. *The Department*

Geological Survey. Annual Progress Report for 1895. Bulletin, No. 4. Note on the discovery of organic remains in the Cairns Range, Western Queensland by R. L. Jack, F.G.S. Stratigraphical Notes on the Georgina Basin, with reference to the question of Artesian water by Robert L. Jack, F.G.S., 1895. The Submarine Leakage of Artesian Water by Robert L. Jack, F.G.S., 1896. ,,

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BUCHAREST—Institutul Meteorologic al Roumăniei. Annales, Tomes IX., X., Année 1893, 1894. *The Institute*

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CALCUTTA—Asiatic Society of Bengal. Journal, Vol. LXIV., Part i., Nos. 2 – 4, Part ii., Nos. 2 and 3, 1895; Vol. LXV., Part ii., No. 1, 1896. Proceedings, Nos. 7 – 10, 1895; No 1, 1896. Annual Address by A. Pedler, E.R.S., 5 Feb., 1896. *The Society*

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CAMBRIDGE—Cambridge Philosophical Society. Proceedings, Vol. VIII., Part v., Vol. IX., Parts i. – iii., 1895-96. Transactions, Vol. XVI., Part i., 1896. *The Society*

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CAPE TOWN—South African Philosophical Society. Transactions, Vol. VIII., Part ii., 1892-95. *The Society*

Surveyor General. Report by Dr. David Gill, Her Majesty's Astronomer at the Cape, on Colonel Morris' Geodetic Survey of South Africa. Fol. Cape Town, 1896. *The Surveyor General*

CARLSRUHE—Grossherzoglich-Badische Technische Hochschule. Programm für das Studienjahr, 1895-96. Lektionsplan 1896. Inaugural Dissertations (5) 1893-95. *The Director*

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CHRISTIANIA—Norwegische Meteorologische Institut. Jahrbuch für 1892. *The Institute*

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DENVER—Colorado Scientific Society. Papers read before the Society, Sept. 9, Oct. 7, Nov. 4, 1895; Jan. 6, April 6, Sept. 7, 1896. *The Society*

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DRESDEN—K. Sachs. Statistische Bureaus. Zeitschrift, Jahrgang XLI., Heft 1–4, 1895-6. *The Bureau*

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GENEVA—Institut National Genevois. Bulletin, Tome XXXIII., 1895. *The Institute*

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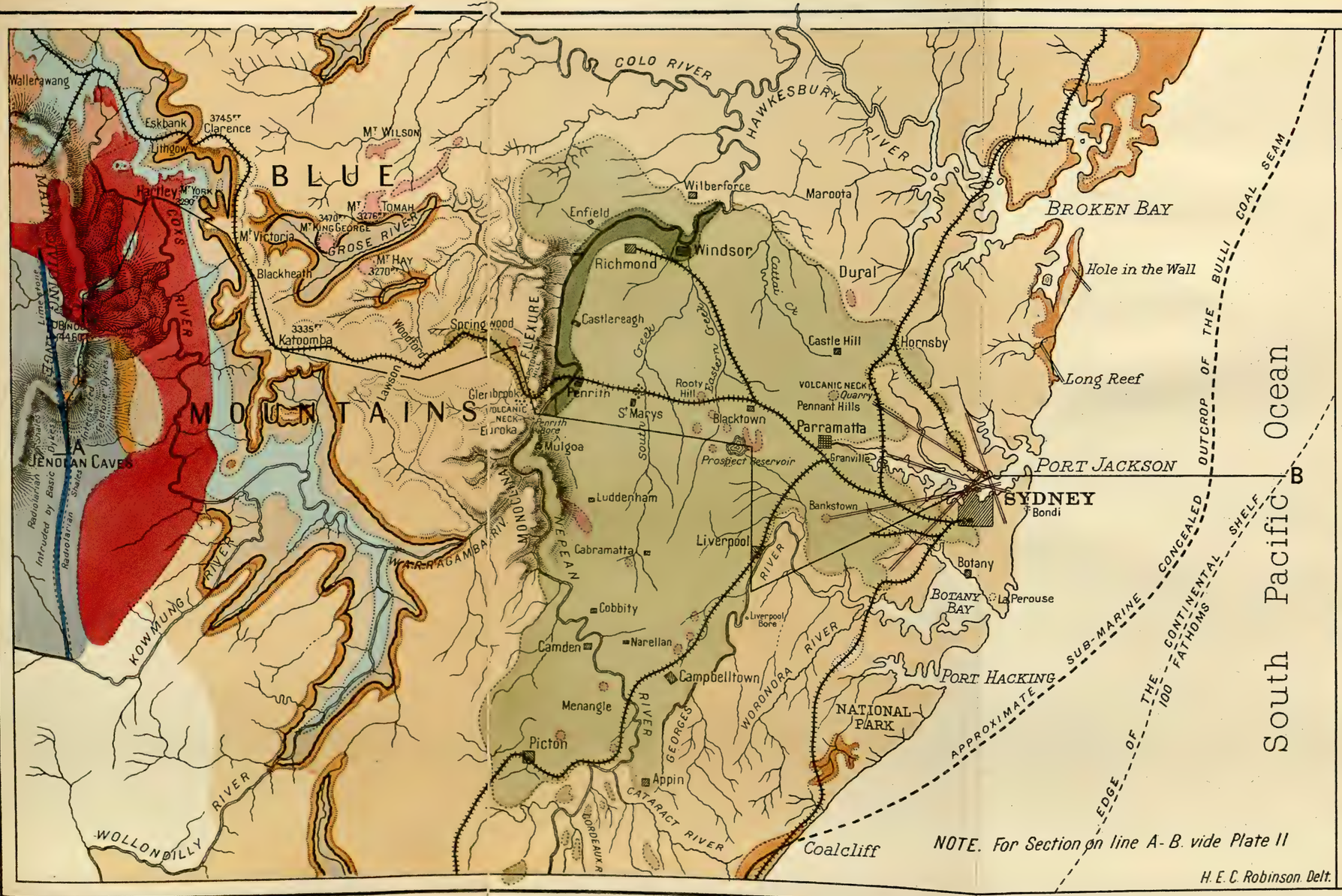


NOTE. For Section on line A-B. vide Plate II

H. E. C. Robinson. Delt.

GEOLOGICAL SKETCH MAP OF THE BLUE MOUNTAINS & COASTAL PLAIN NEW SOUTH WALES

Based chiefly on the Geological Map of the Rev. W. B. Clarke and of that published by the Geological Survey. Dep^{t} of Mines

Scale of Miles

0 5 10 20 30

INDEX

- CARBONIFEROUS. *Granite*
- TERTIARY. EOCENE? *Basalt and Dolerite*
- SILURIAN. *Claystones with casts of radiolaria above and below the Cave Limestone. The latter is about 330 feet thick and contains Stromatopora, Favosites, and numerous large Pentameri.*
- UPPER DEVONIAN TO CARBONIFEROUS? *Quartzites with Spirifera Disjuncta, Argillite and Graywacke with Lepidodendron Australe.*
- PERMO-CARBONIFEROUS. *Mudstones with large boulders and soft sandstones of the Upper Marine Series*
- PERMO-CARBONIFEROUS. *Coal measures of the Newcastle-Bulli Series. with Glossopteris Gangamopteris, Vertebraria etc.*
- TRIASSIC? *Narrabeen Beds of Hawkesbury Series with Thinnfeldia, Odontopteroides, Oleandridium, Phyllotheca etc. and remains of Mastodonsauridæ.*
- TRIASSIC? *Hawkesbury Sandstone with fossils similar to above with exception of Oleandridium.*
- TRIASSIC? *Wianamatta Shales of Hawkesbury Series with fossils similar to above with the addition of numerous dwarf unios and unionellæ.*
- CRETACEO-TERTIARY. *River Gravels of Lapstone Hill and St Marys.*
- PLEISTOCENE & RECENT. *Alluvial deposits of the Nepean River.*

LONGITUDINAL SECTION
THROUGH
BLUE MOUNTAINS & SYDNEY COALFIELDS
from Jenolan Caves to Edge of Continental Shelf
N.S.W

Diagram 1

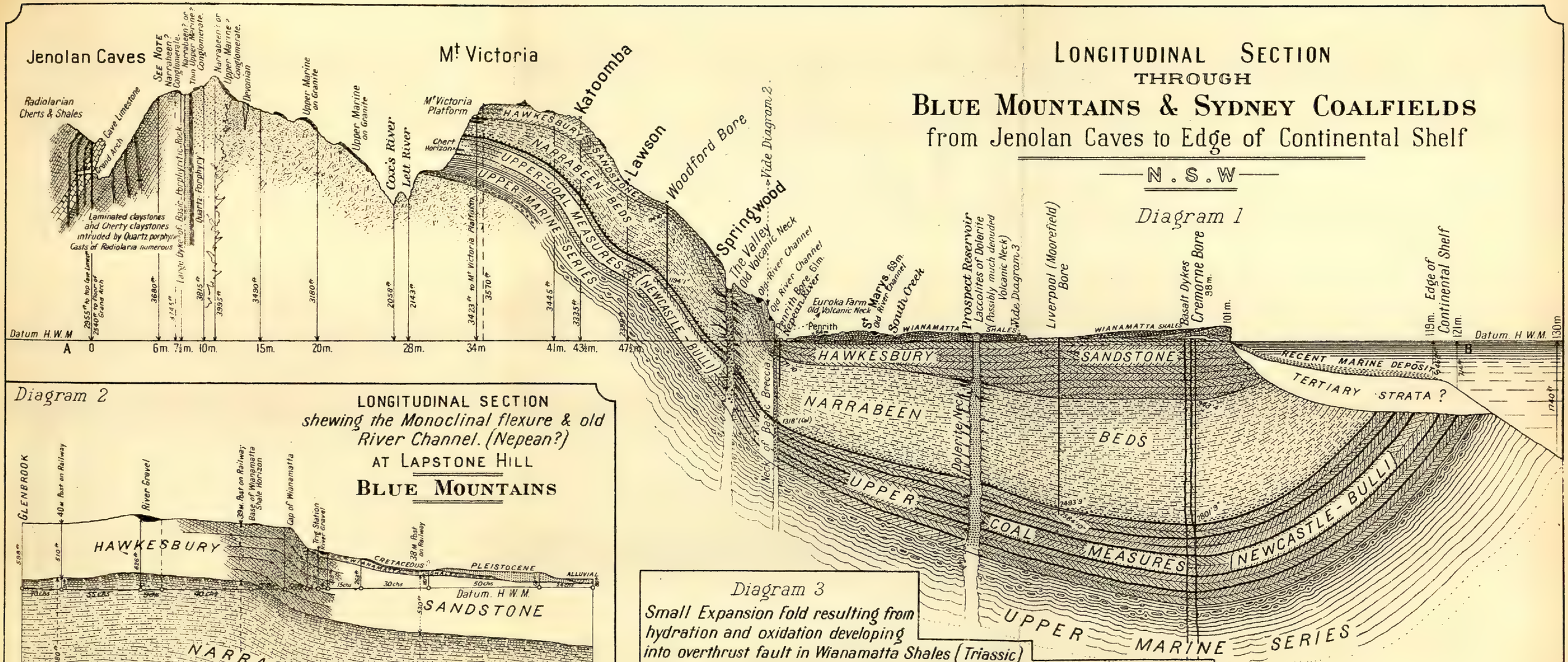


Diagram 2

LONGITUDINAL SECTION
shewing the Monoclinal flexure & old River Channel. (Nepean?)
AT LAPSTONE HILL
BLUE MOUNTAINS

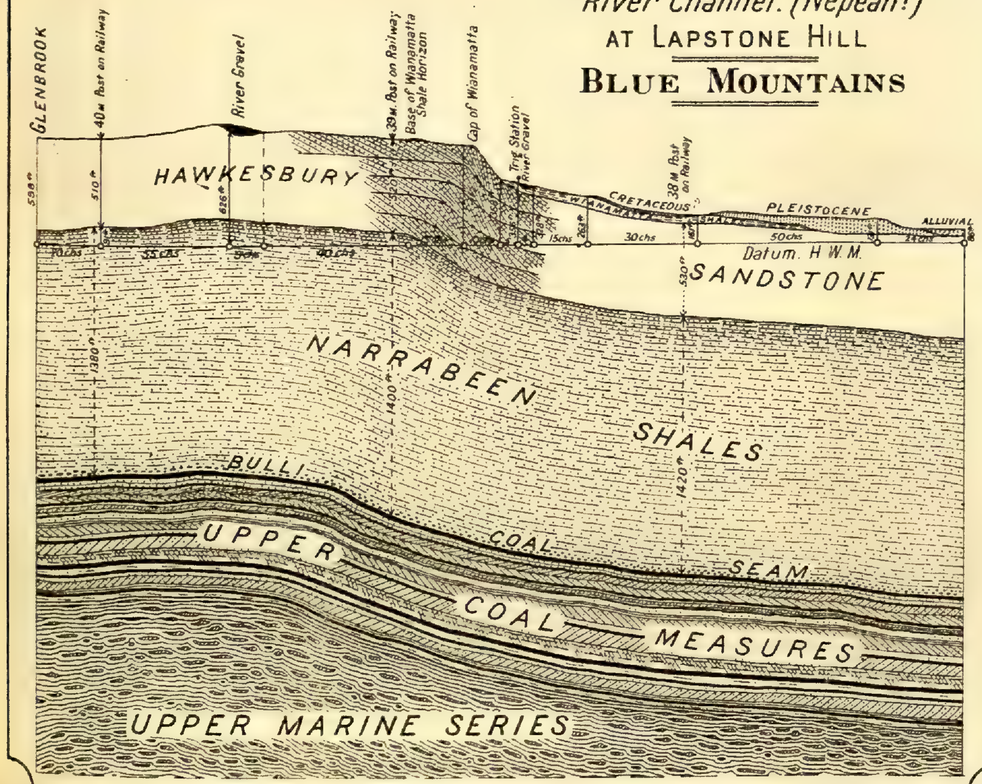


Diagram 3

Small Expansion Fold resulting from hydration and oxidation developing into overthrust fault in Wianamatta Shales (Triassic) Opposite 16 mile mark from Sydney on Western Railway line N.S.Wales

For line of Section A to B see Plate I.

NOTE

In the text it is stated that there is probable evidence of unconformity here, between the Devonian and Silurian rocks. Possibly however the supposed Devonian Conglom-erates belong to the Triassic Narrabeen Beds.

H. E. C. Robinson Delt

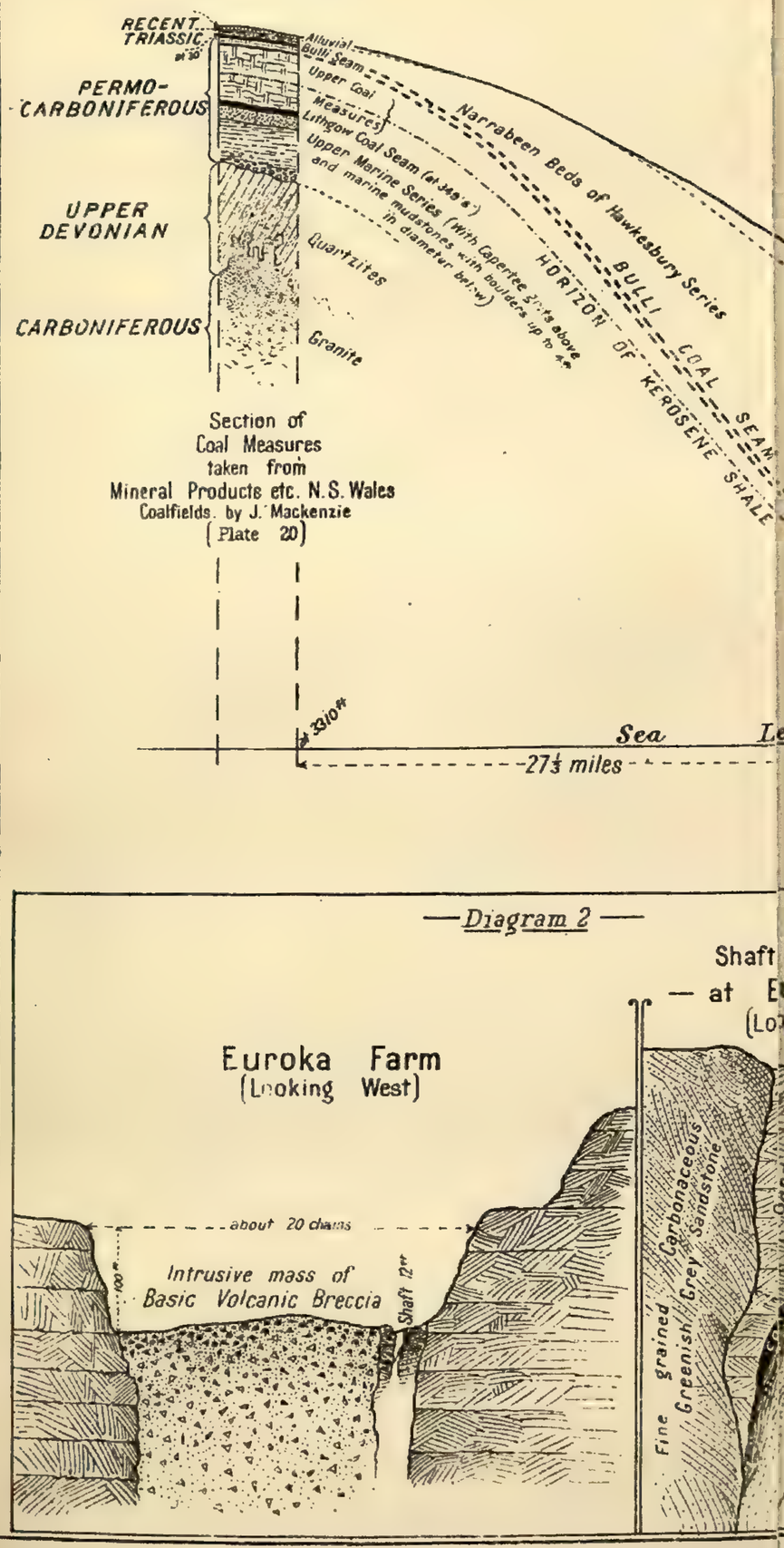
COMPARATIVE SERIES OF VERTICAL SECTIONS

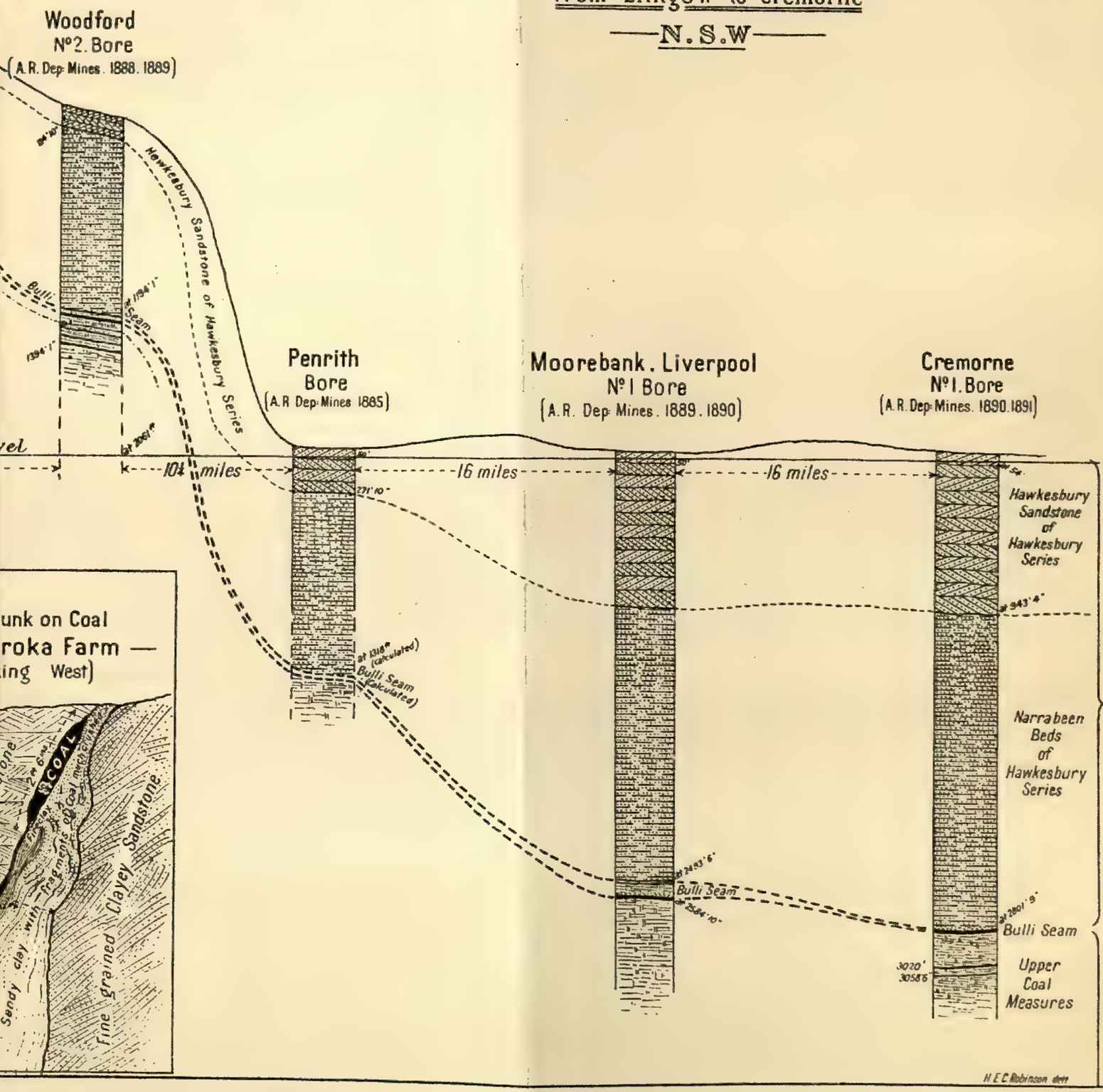
— IN THE —

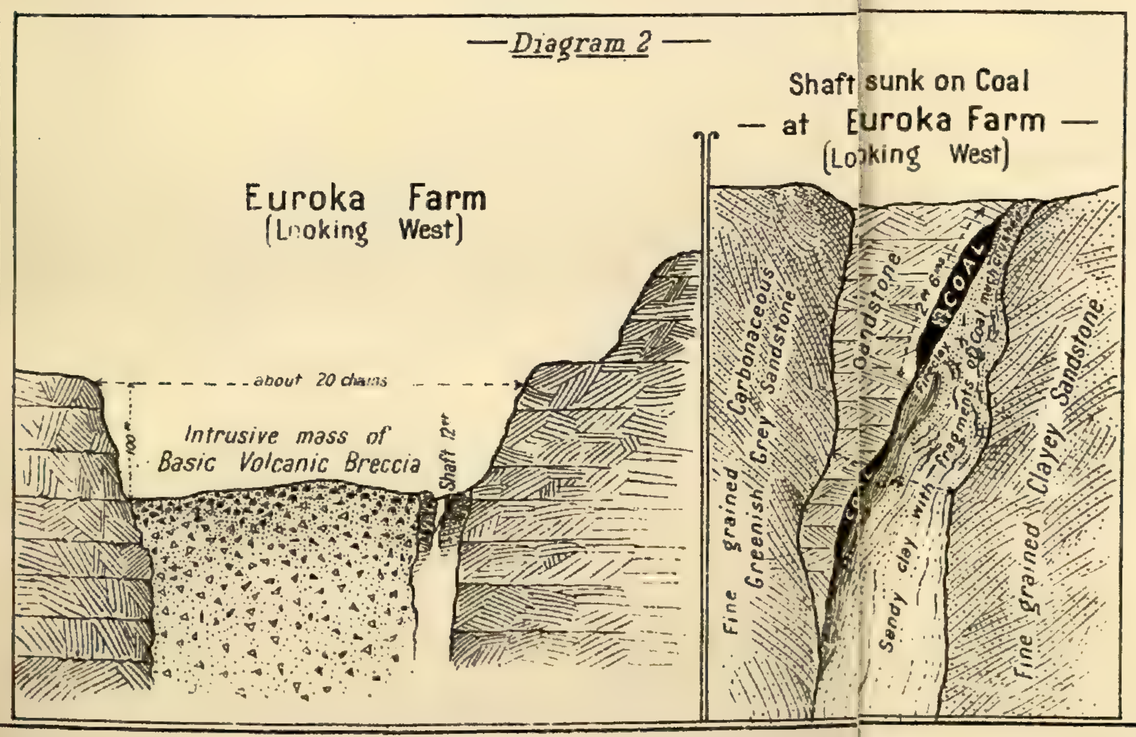
BLUE MOUNTAIN AND SYDNEY COALFIELDS

From Lithgow to Cremorne

—N.S.W—







MAP

shewing the relation of the fold of the

BLUE MOUNTAINS

to the chief directions of folding at present known in

AUSTRALIA ❖ TASMANIA AND NEW ZEALAND

The Anticlines of the New Zealand folds are reproduced from the sketch by Capt[n] Hutton. F.R.S (Quart. Jour. Geol. Soc. May 1885) and the folds of West Australia from the Handbook of W. Australia by H. P. Woodward. F.G.S. 1892

LONG 135° E.

NEW GUINEA

Port Darwin

Kimberley District

MACDONNELL RANGES

Tasmanian

MUSGRAVE RANGES

Murchison Goldfield

Coolgardie Goldfield

Perth

Adelaide Axes

Gilbert

Burdekin

Charters Towers

Cape

Peak Downs

of Gympie Axes

Tropic of Capricorn

Rockhampton

Brisbane

Silverton

New England

Axes

Kosciusco Axes

BLUE MTS

Sydney

Adelaide

Melbourne

1000 fathom line

1000 FATHOMS DEEP

OVER 1000 FATHOMS

NEW CALEDONIA

Lord Howe Isd

Norfolk Isd

TASMANIA

NEW ZEALAND

Te Anau fault

LONG 165° E.

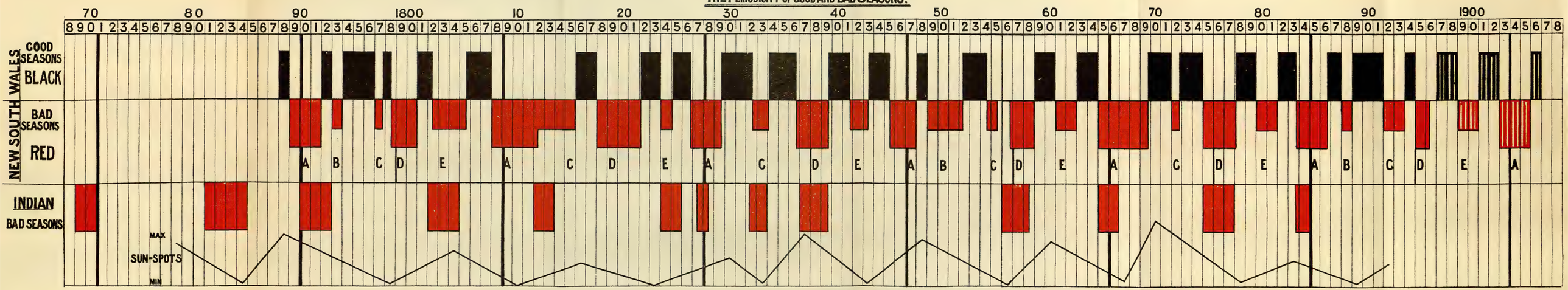
Explanation

Observed lines of folding. thus ——

Probable continuation of same. „ ------

H E C Robinson. Delt

THE PERIODICITY OF GOOD AND BAD SEASONS.



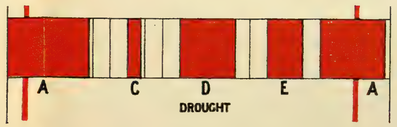
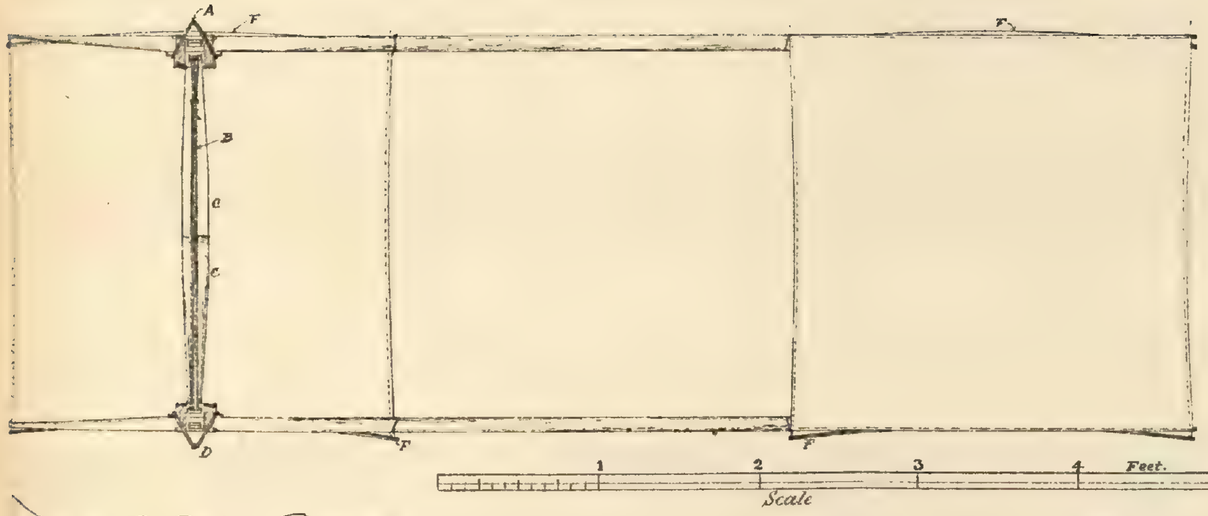
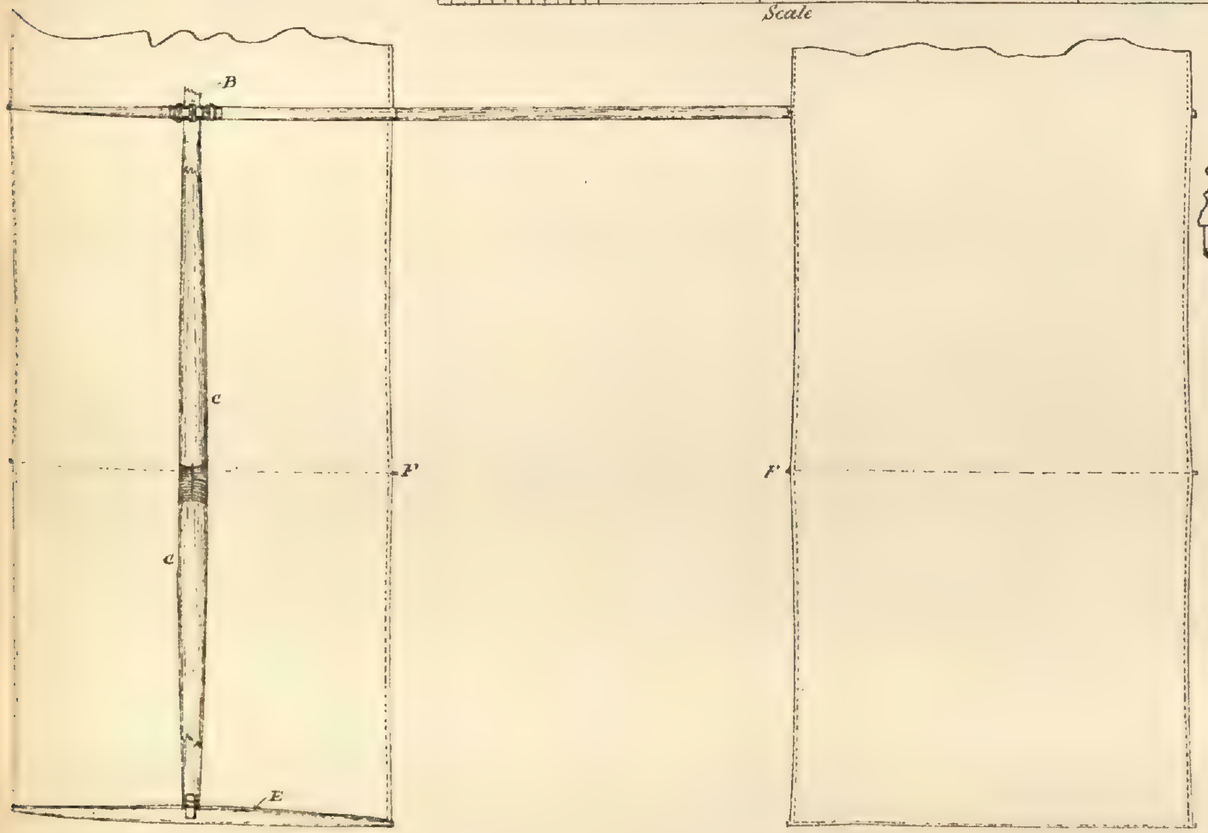


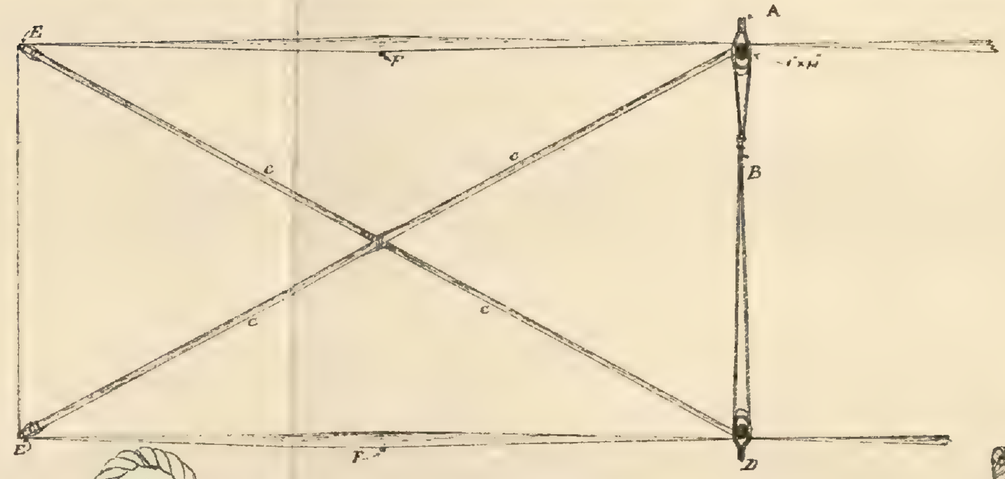
DIAGRAM SHEWING GOOD AND BAD SEASONS IN NEW SOUTH WALES FROM 1788 TO 1896
ALSO BAD SEASONS IN INDIA
MAXIMA AND MINIMA OF SUN-SPOTS

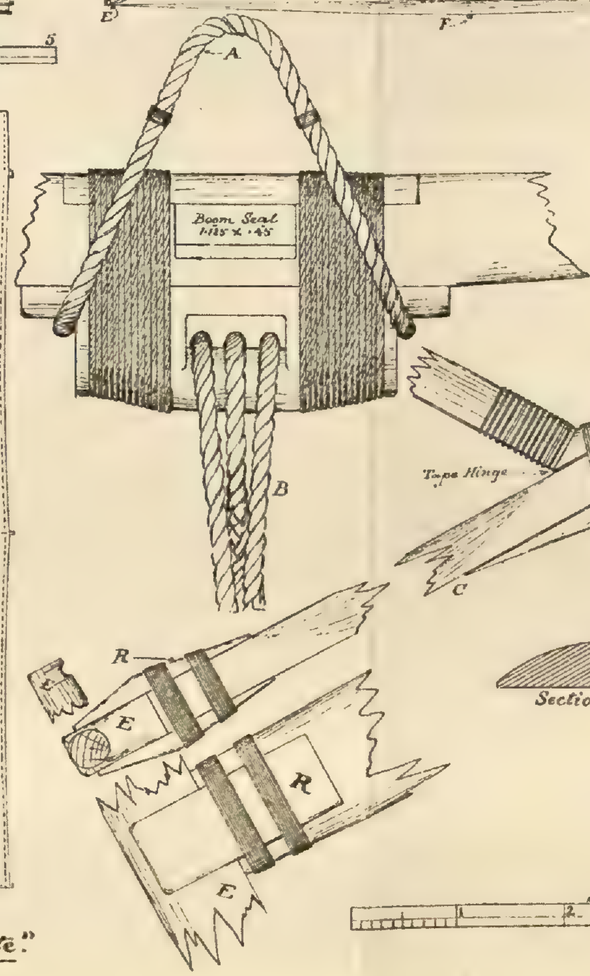
5d41-95-6

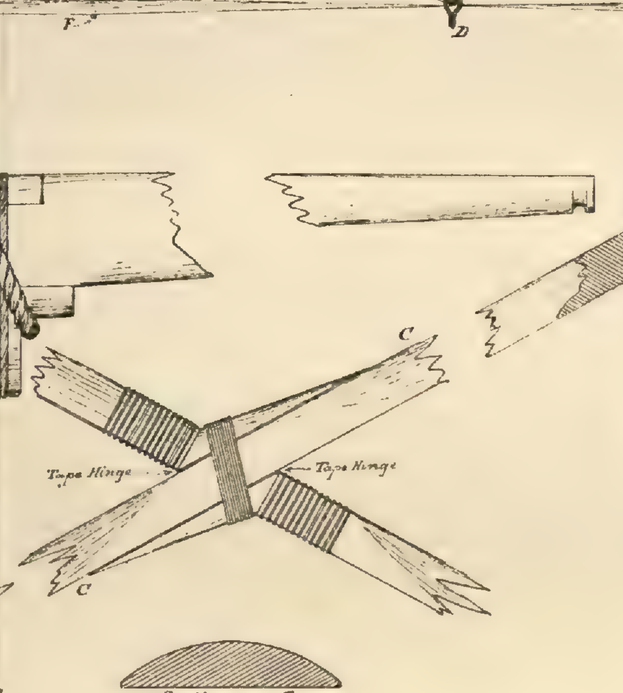
PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE, SYDNEY, NEW SOUTH WALES.











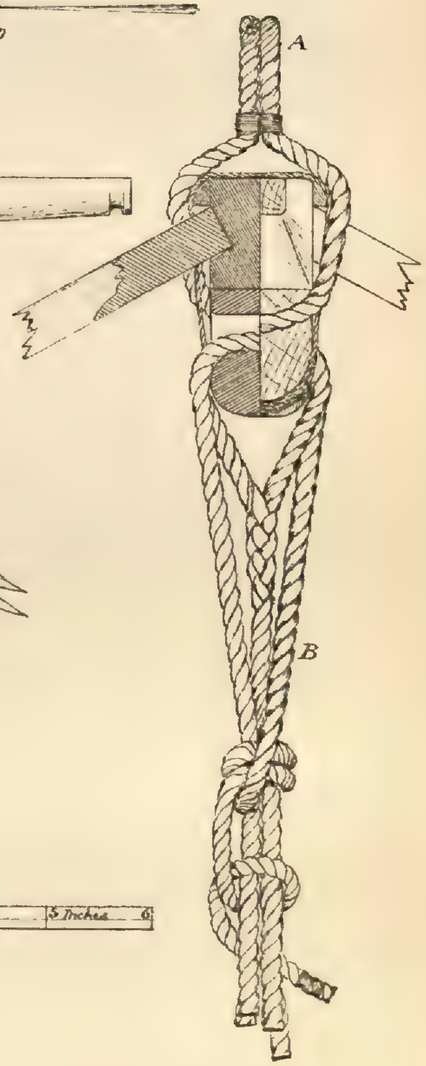


Diagram for L. Hargrave's Paper on "The Cellular Kite."

Journal Royal Society of N.S.W. Vol. XXX. 1896.

Diagram 1

Shea's Creek Canal . Sydney . N.S.W

SKETCH PLAN

shewing position of Submerged Forest, Remains of Dugong, Stone Tomahawks &c

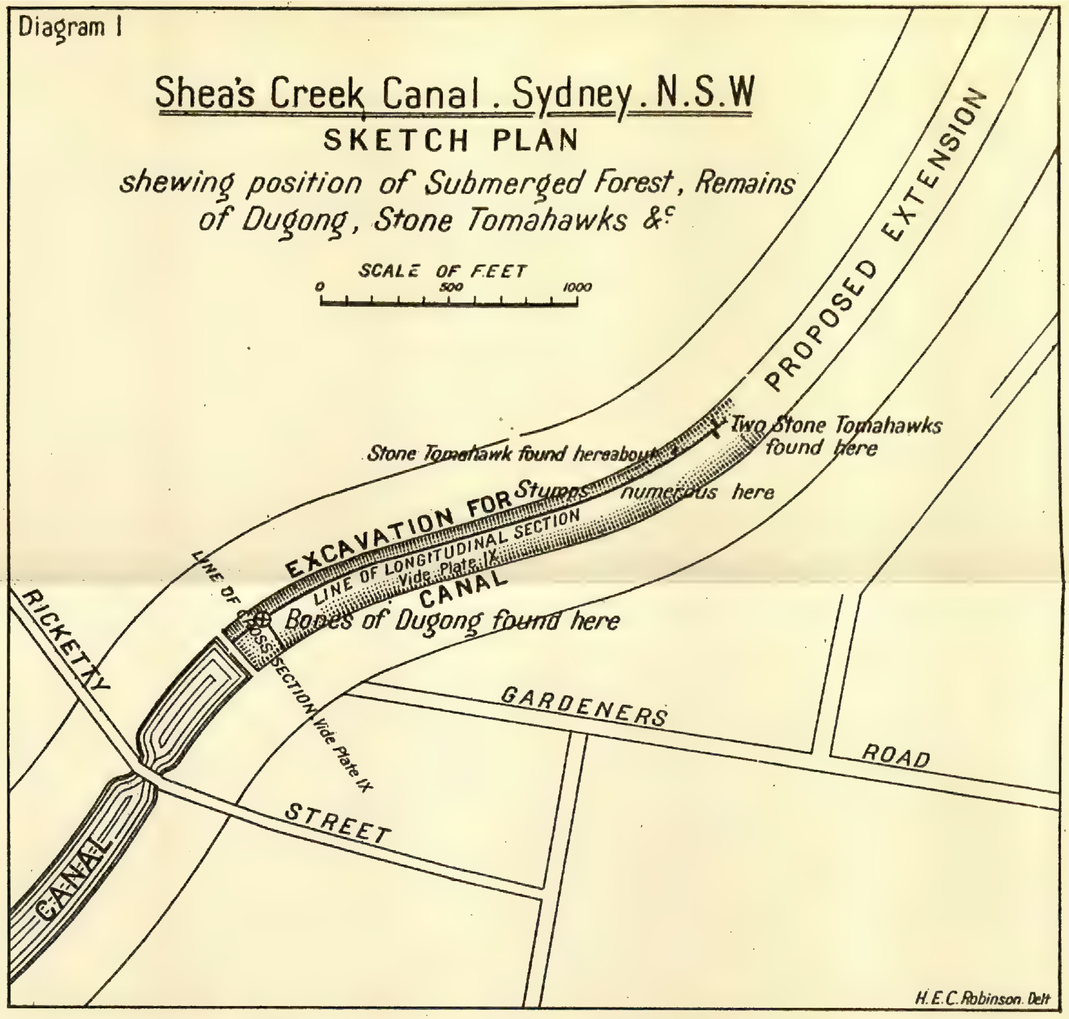
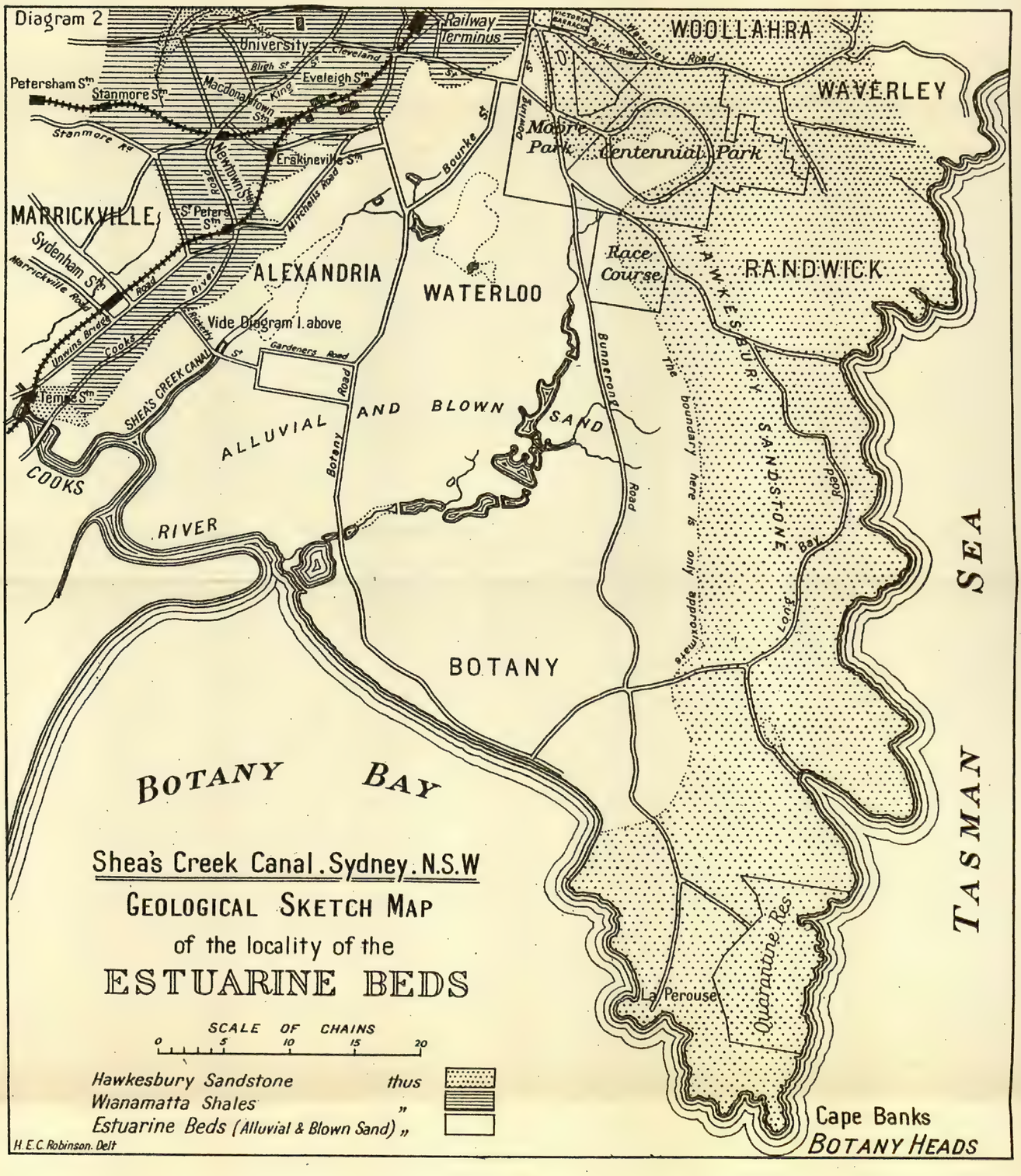


Diagram 2



Shea's Creek Canal . Sydney . N.S.W

GEOLOGICAL SKETCH MAP

of the locality of the

ESTUARINE BEDS

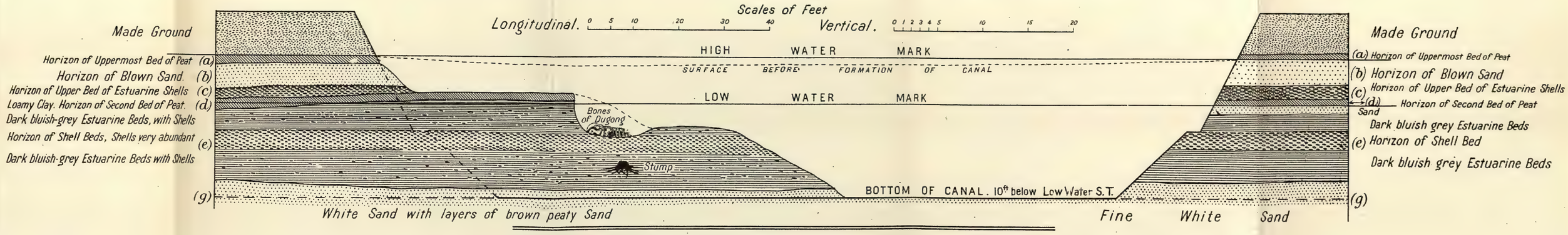
SCALE OF CHAINS 0 5 10 15 20

Hawkesbury Sandstone thus
Wianamatta Shales "
Estuarine Beds (Alluvial & Blown Sand) "

H.E.C. Robinson. Delt

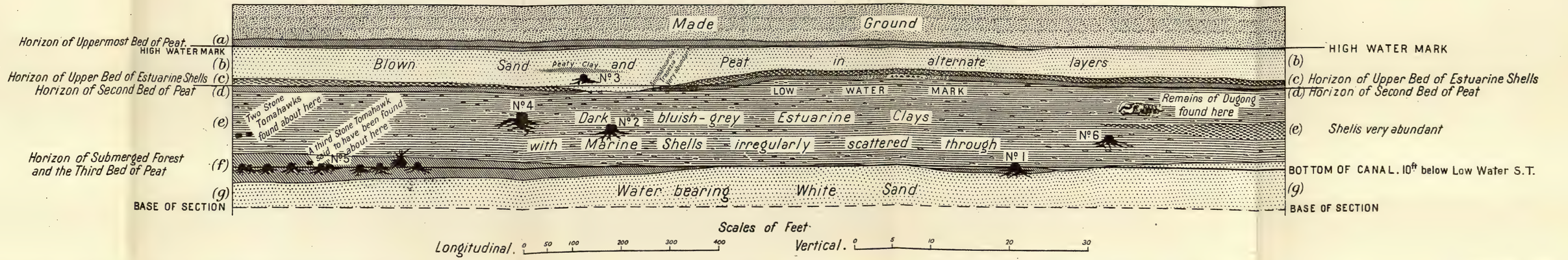
Shea's Creek Canal . Sydney . N.S.W

CROSS-SECTION shewing where bones of Dugong were discovered 3ft below Low Water



Longitudinal Section of Estuarine Beds

From between 550ft and 2700ft North East of Rickety Street
shewing position of Submerged Forest, Remains of Dugong, Stone Tomahawks etc

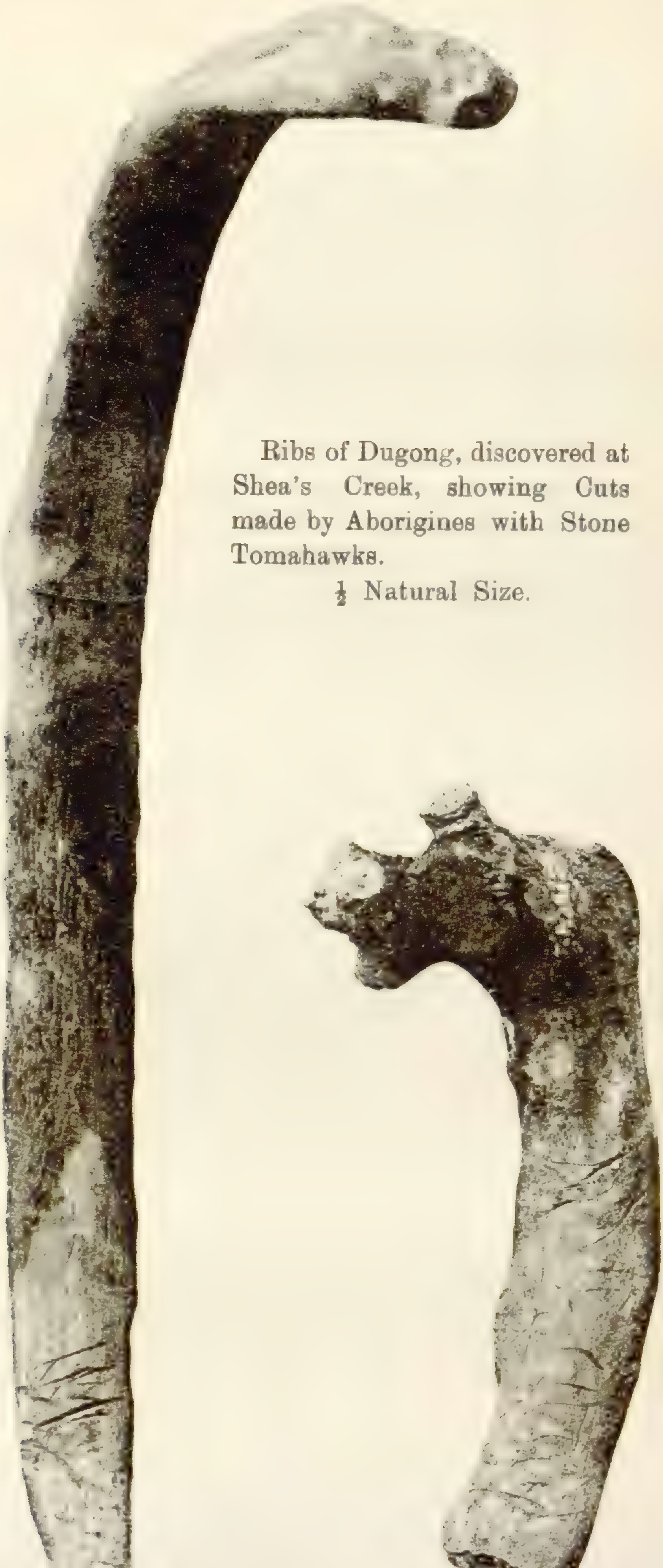


H. E. C. Robinson. Delt. Sydney

Skull of Dugong, discovered at Shea's Creek, Sydney. ¼ Natural Size.

Lower Jaw of Dugong, discovered at Shea's Creek, Sydney, showing Cuts made by Aborigines with Stone Tomahawks.

½ Natural Size.

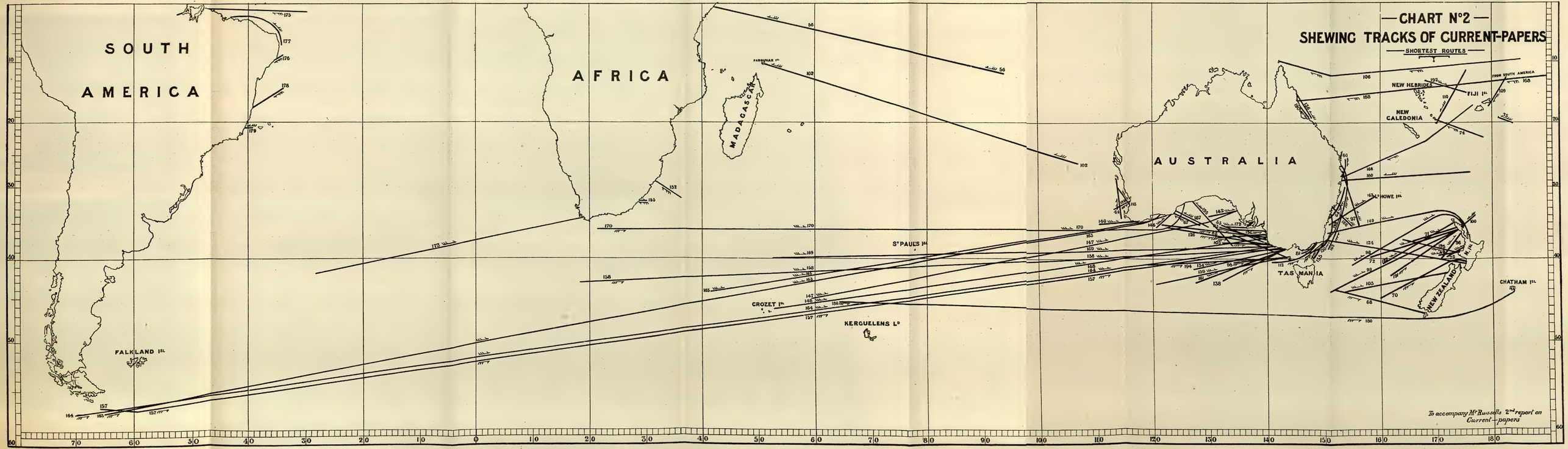


Ribs of Dugong, discovered at Shea's Creek, showing Cuts made by Aborigines with Stone Tomahawks.

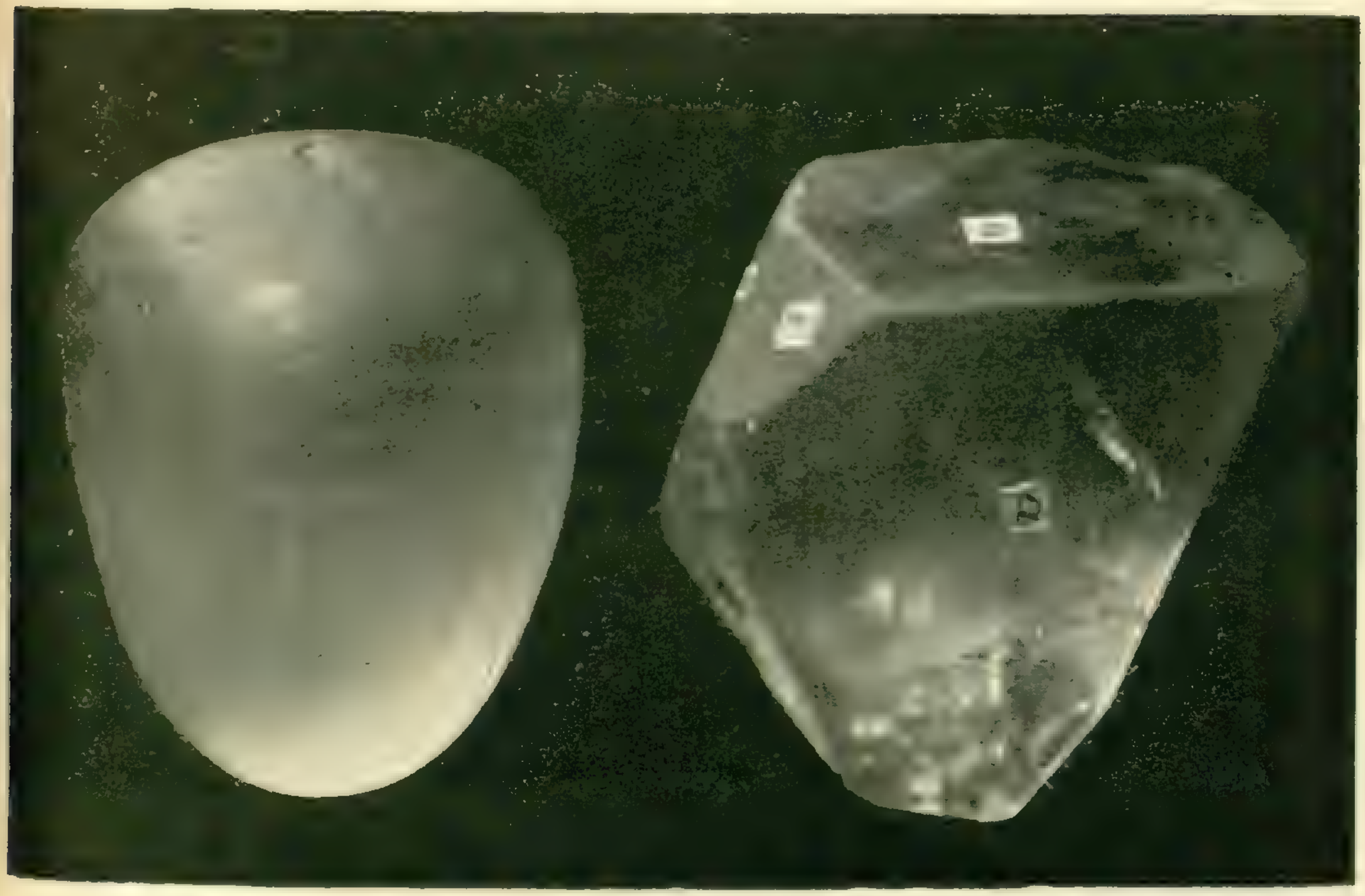
½ Natural Size.

Skeleton of the Dugong found at Shea's Creek.

SCALE ONE FOOT.


SOUTH AMERICA
AFRICA
AUSTRALIA
MADAGASCAR
FALKLAND Is.
CROZET Is.
St PAULS Is.
KERGUELENS L.
NEW HEBRIDES
FIJI Is.
NEW CALEDONIA
LORD HOWE Is.
TASMANIA
NEW ZEALAND
CHATHAM Is.
FROM SOUTH AMERICA
— CHART N°2 —
SHEWING TRACKS OF CURRENT-PAPERS
SHORTEST ROUTES
To accompany Mr Russell's 2nd report on Current-papers

(1250-96)



FIGS. 1 AND 2.—TOPAZ, NEW ENGLAND. *Three-fifths natural size.*

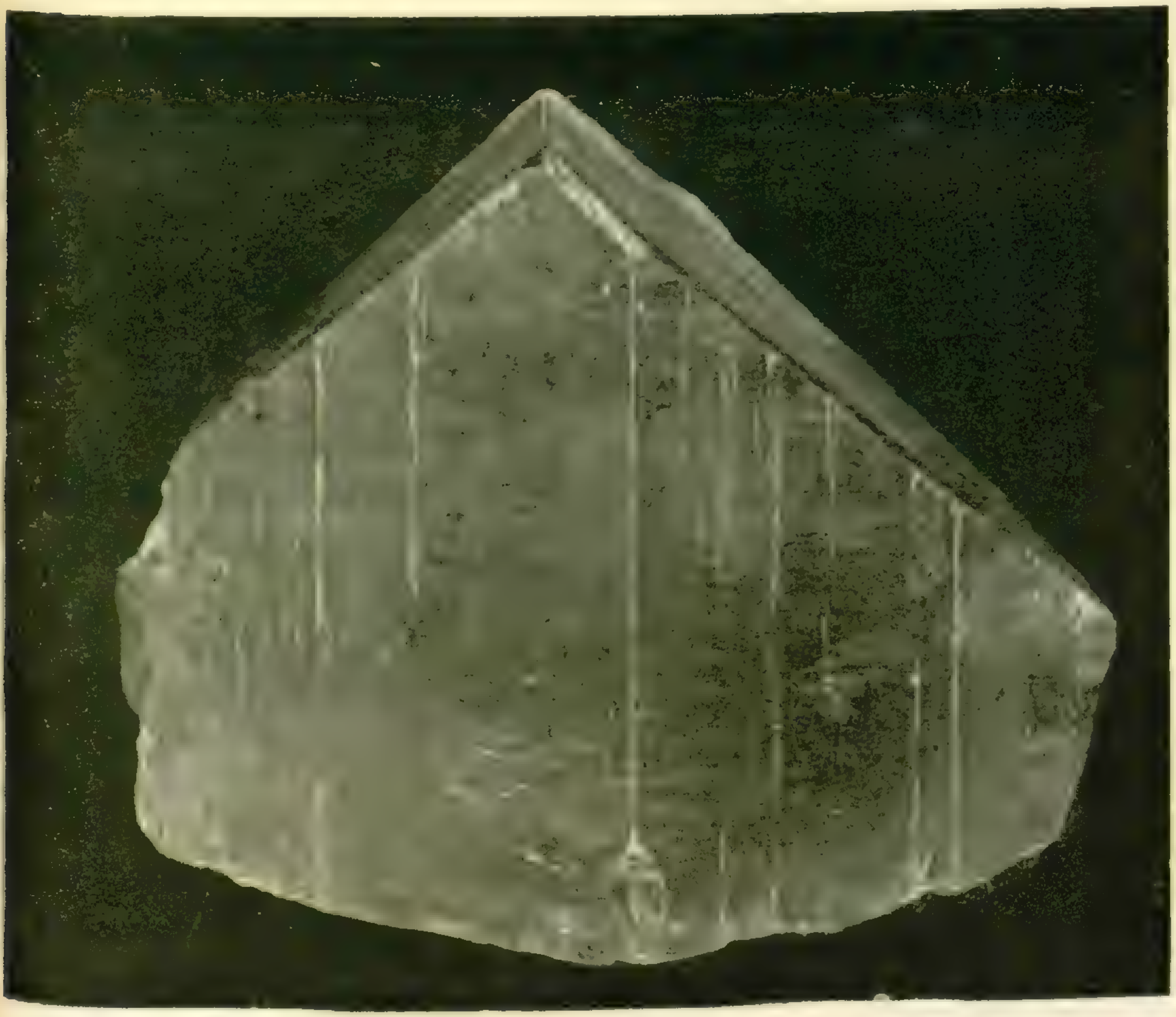


FIG. 3.—A CRYSTAL OF TOPAZ, OBAN. *Natural size.*

J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

TOPAZ, NEW SOUTH WALES.

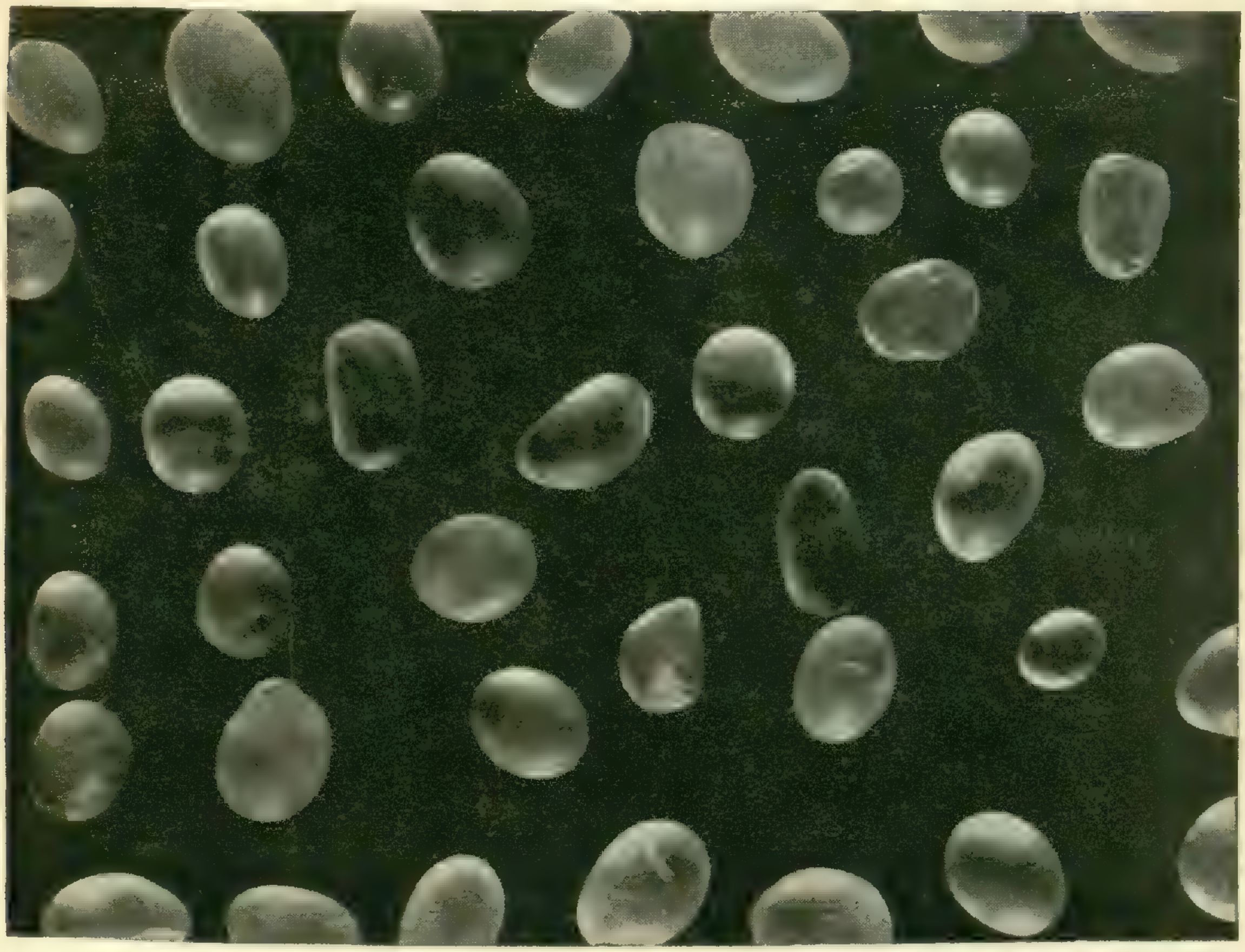


FIG. 1.—WATER-WORN TOPAZ, EMMAVILLE. *Natural size.*

FIG. 2.—FRAGMENT OF TOPAZ AS FOUND, NEW ENGLAND. *One half natural size.*

J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

TOPAZ, NEW SOUTH WALES.

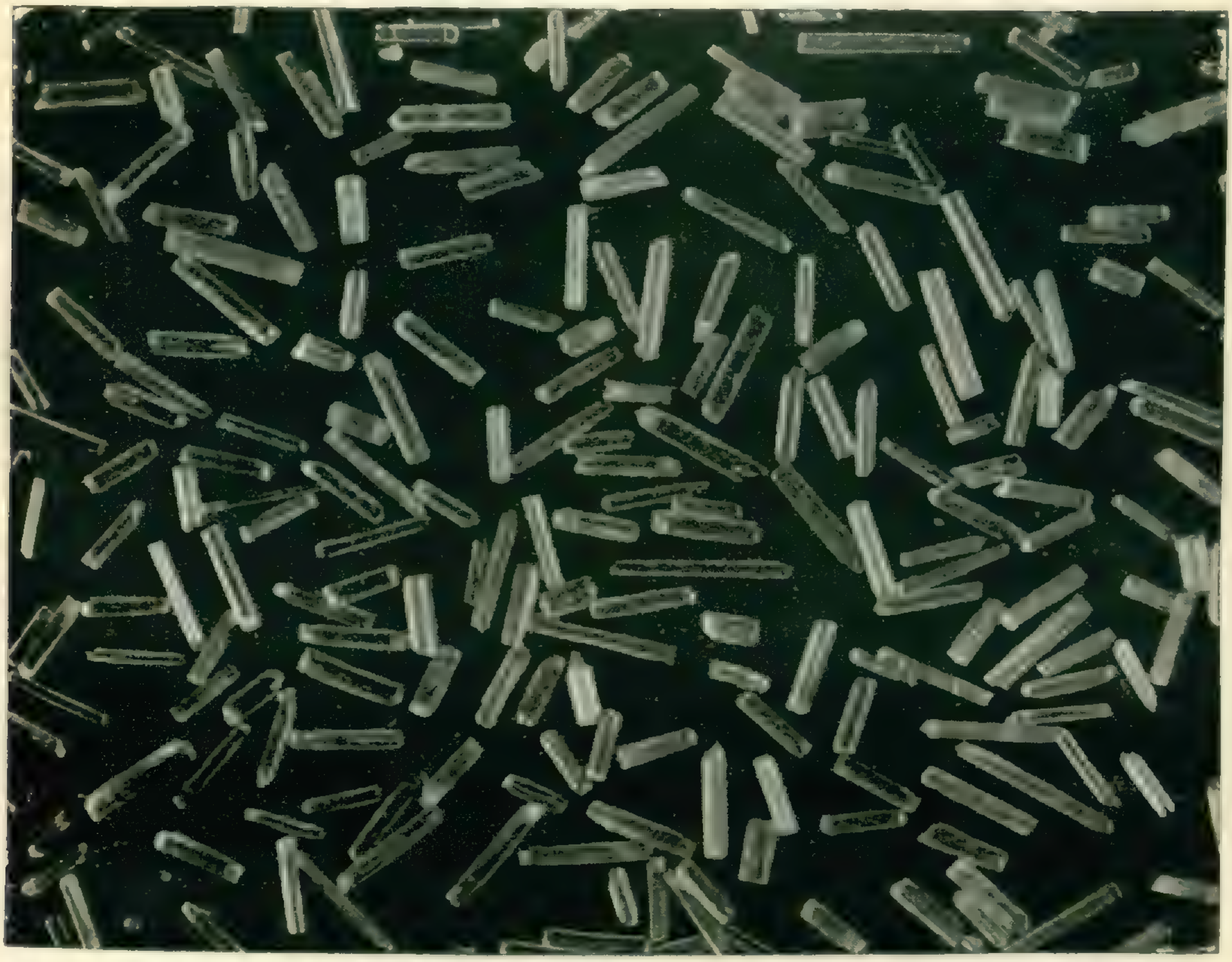


FIG. 1. BERYL AND EMERALD, EMMAVILLE *Natural size.*

FIG. 2.—BERYL AND EMERALD, AS FOUND IN DRIFT, NEW ENGLAND. *Natural size.*

J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

BERYL AND EMERALD,
NEW SOUTH WALES.

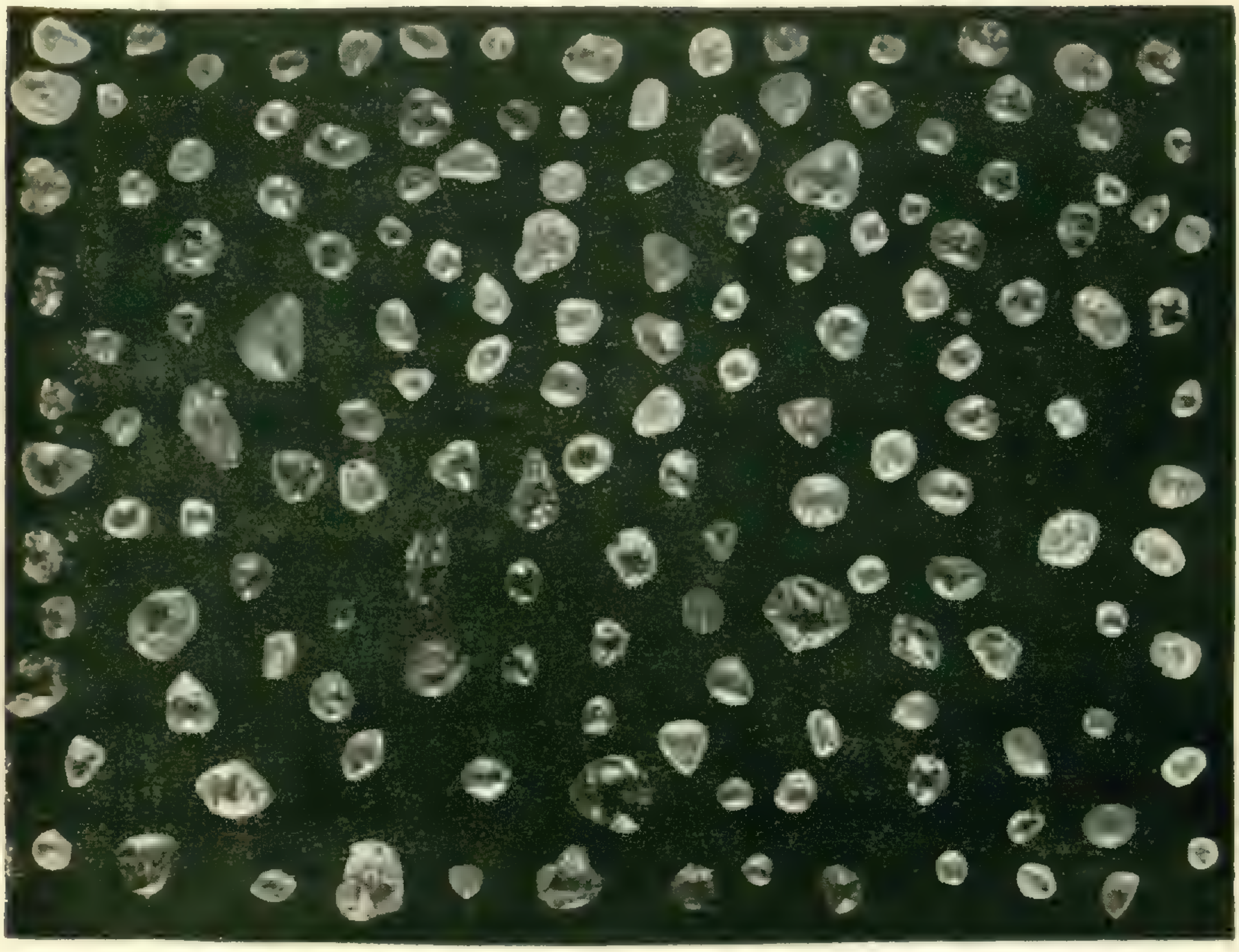


FIG. 1. DIAMONDS, BINGARA. *Natural size.*

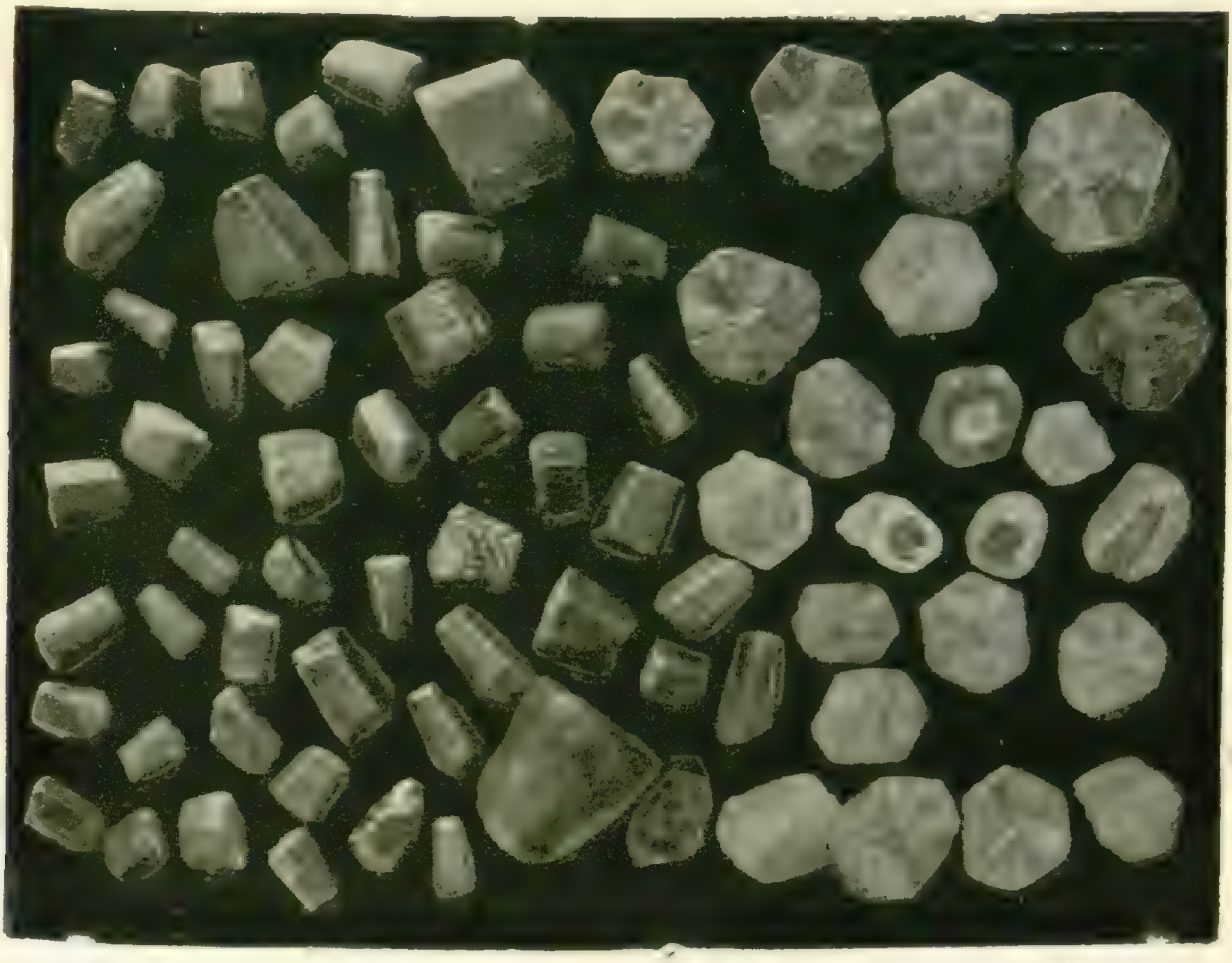


FIG. 2.—SAPPHIRE, AS FOUND WITH TIN-STONE, EMMAVILLE. *Natural size.*

J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

DIAMONDS AND SAPPHIRE.

NEW SOUTH WALES.

FIG. 1.—OPAL IN A MATRIZ OF SILICEOUS IRONSTONE, QUEENSLAND. *One-half natural size.*

FIG. 2.—OPAL, AS FOUND IN SEAMS, WHITE CLIFFS, N. S. WALES. *One-half natural size.*

J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

OPALS, NEW SOUTH WALES AND QUEENSLAND.

J. M. Curran, Photo.

FIG 1.—SLUICING-BOX FOR TIN-STONE, EMMAVILLE. SAPPHIRE IS FOUND WITH THE TIN-STONE.

Enameline Photo. Eng. Co.

FIG. 2.—CRADLE USED FOR GOLD SAVING, TUMBERUMBA. ZIRCON, SAPPHIRE, AND CYANITE ARE ALSO SAVED.

FIG. 1.—OPAL MINE, WHITE CLIFFS.

FIG. 2.—ASPECT OF DIAMOND-BEARING COUNTRY, BINGARA.

J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

OPAL, AND DIAMOND COUNTRY,

NEW SOUTH WALES.

FIG. 1.—SILURIAN SLATE, STURT'S DEPOT GLEN, TIBBOBURRA.

FIG. 2.—CLIFF AND TALUS IN CRETACEOUS COUNTRY, NEAR TIBBOBURRA.

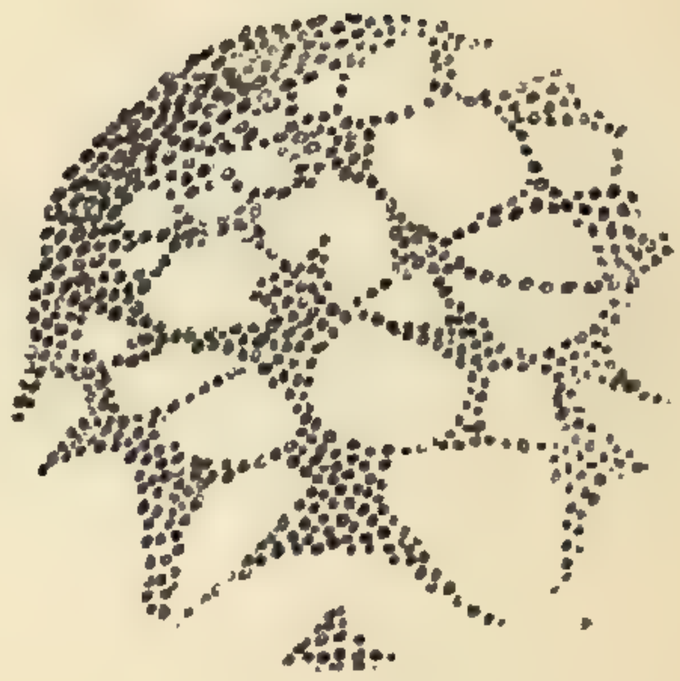
J. M. Curran, Photo. *Enameline Photo. Eng. Co.*

SILURIAN AND CRETACEOUS COUNTRY,

NORTH-WESTERN NEW SOUTH WALES.

Andropogon annulatus, Forsk. Different stages of Manna.

1



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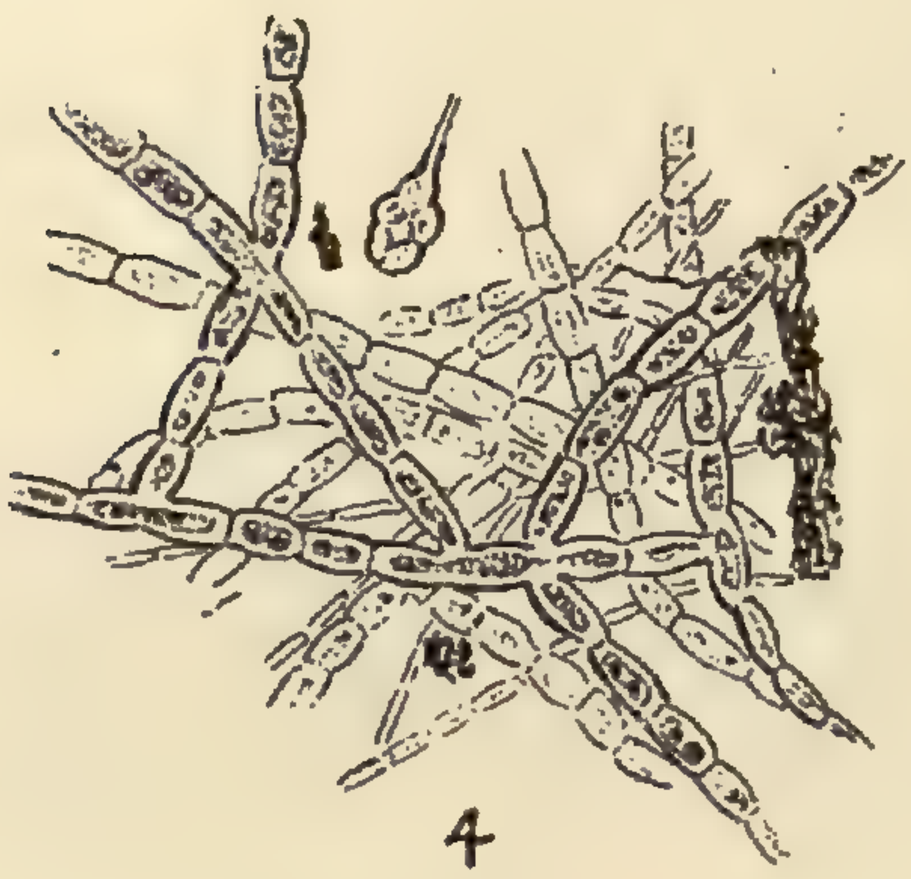

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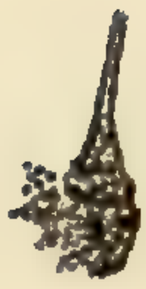

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5

R. T. Baker
del. et lith.

Mannitè crystals and Life History of Saccharomyces sp.

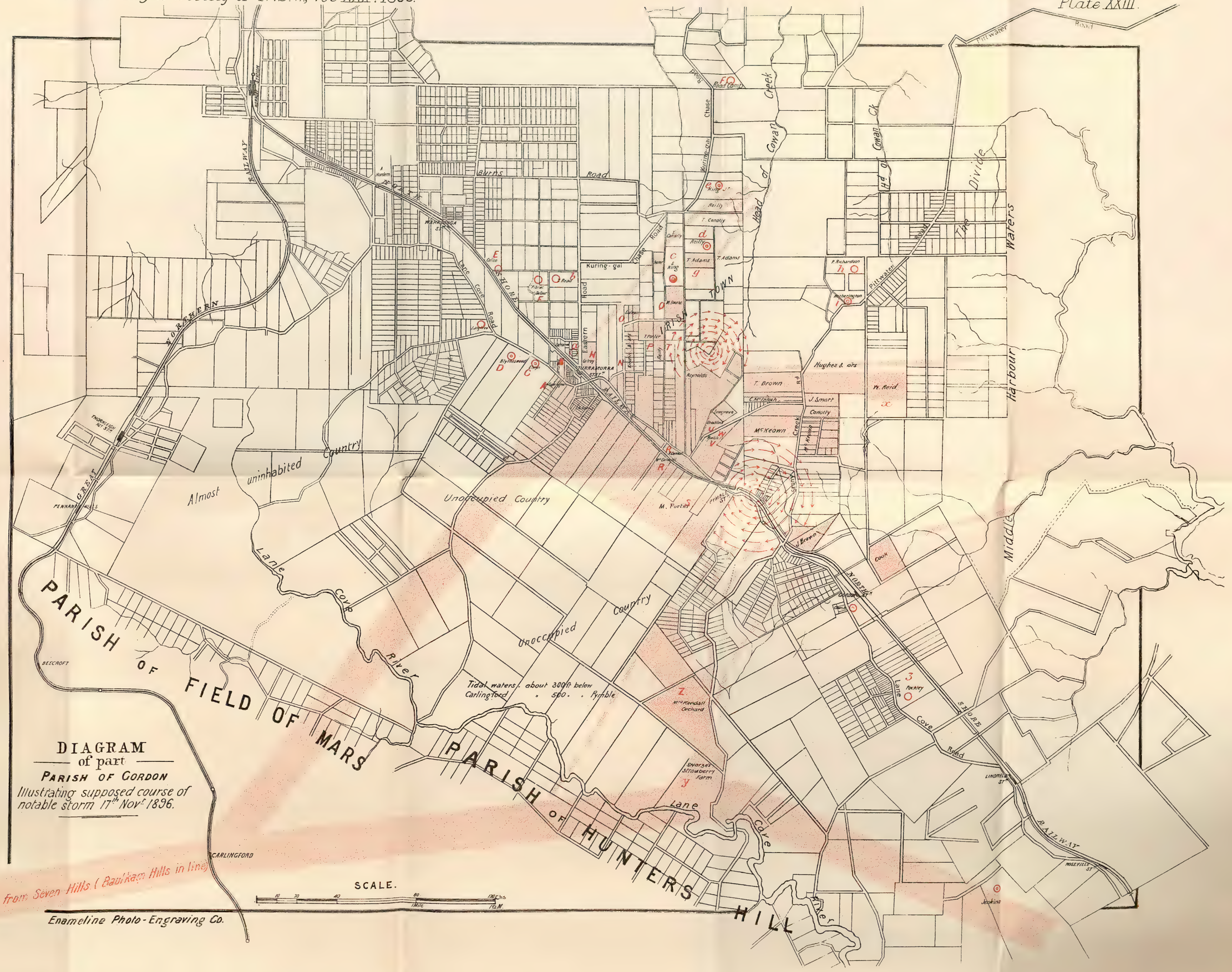

DIAGRAM
of part
PARISH OF GORDON
Illustrating supposed course of notable storm 17th Novr 1896.

N 10° E from Seven Hills (Baulkam Hills in line)

Enameline Photo-Engraving Co.

ANNUAL ADDRESS.

By W. H. WARREN, Wh. Sc., M. Inst. C.E., M. Am. Soc. C.E.,

Professor of Engineering in the University of Sydney.

[*Delivered to the Engineering Section of the Royal Society of N. S. Wales, June 17, 1896.*]

IN the first place allow me to thank you for the honour you have done me in electing me as your Chairman for this year. As many of you know I was one of those who considered that the formation of an Engineering Section of the Royal Society was very desirable, and in 1891 the first meeting was held under the Chairmanship of Mr. C. W. Darley. Since the formation of this Section I have always taken a great interest in everything which concerned its welfare, as I believe that meeting together as we do to night, in order to discuss matters of professional interest, not only advances the interest of the profession to which we belong by increasing the aggregate amount of useful knowledge, but by establishing personal relationships between its members, renders it a much more easy and pleasant task to deal with the many practical problems which present themselves in the every day work of the engineer, besides stimulating us in attempting the more difficult problems which await solution in the future.

One of the considerations which led to the formation of the Engineering Section of the Royal Society was the fact that so many of its members were also members of the Institution of Civil Engineers, London. The four gentlemen whom I have the honour to succeed to-night as Chairman, the members of the Committee, and nearly all the ordinary members of the Section, are engineers engaged in the practice of their profession. The success of a society such as this, depends mainly upon the individual efforts of its members, in bringing under its notice the results of their experience, in the form of papers for consideration and discussion. I am most anxious to maintain, and as far as possible

to increase the advantages of these meetings, and I trust that you will accord to me the same loyal support which you have given to my predecessors.

Since I was last at these meetings an Engineering Society has been formed at the University for the graduate and undergraduates in Engineering, and as the former are members of this Society and have contributed to its proceedings, I have no doubt that the University Society will act as a feeder to our membership, just as the graduates act as feeders to the ranks of the profession. The importance of a sound scientific knowledge as a basis of engineering practice, is so universally acknowledged, that there is no necessity for me to enlarge upon it to-night. In order to succeed as an engineer, it is indispensable that a man should have a thorough knowledge of the scientific principles which underlie the practice of his profession. It is therefore with great pleasure that I am able to say, that the munificent gift of our noble benefactor Mr. P. N. Russell, will enable us to make the future training of our engineering graduates exceptionally complete. It was my privilege to meet Mr. P. N. Russell when I was last in England, and I am particulary gratified in the fact that our Engineering School will in the future bear his honoured name, which will go down to posterity not merely in connection with the wealth which he so generously bestowed, but also as the most successful of the pioneer engineers in Australia, and further, as one who bestowed his wealth during his life for the benefit of the future engineers of this country. During my recent trip, I devoted myself to the study of the methods employed and the works produced by engineers in America, England, and Europe, and at the request of my engineering friends, I propose to night to briefly lay before you some of the information I have collected.

I will first direct your attention to the subject of railways. The Western Trans-continental Railway crosses the Sierra Nevada range of mountains, reaching the summit level 7,017 feet above sea-level, at a distance of one hundred and ninety-five miles from San Francisco. The ruling gradient on this line is one in forty-

six, and the sharpest curve is twelve degrees or four hundred and seventy-seven feet radius. There are steeper grades and sharper curves crossing the Rocky Mountains to Colorado, and the summit height is over 10,000 feet above sea-level. At Colorado the railway up Pikes' Peak, which ascends to a height of about 14,000 feet above sea-level, is constructed on the Abt system. The gradients contain some long stretches of one in four. The locomotive used is of special construction, and there is a double rack, laid midway between the ordinary rails, into which gears a spur pinion carried on the engine. The speed attained is about five miles an hour. At Denver, on the Union Pacific Railway, there are some excellent examples of cheap railway construction, some of the cross sections consist of an earth road bed, which is used without ballast, where earth of a suitable character exists, both in cuttings and embankments; other cross sections show ballast consisting of gravel, cinder, burnt clay or broken stone. The rails are of the ordinary American section, and weigh from forty to seventy-five pounds per lineal yard, with angle fish-plates at the joints; the sleepers consist of pine or red spruce timber, spaced generally, about nineteen inches apart, centre to centre, and sixteen inches apart at the joints. The formation is always thorougly drained, and in the earth road it is arched up forming a convex surface, which rapidly discharges the rainfall to the side drains. The abundance of cheap timber of suitable quality has resulted in a very free use of timber viaducts, not merely as flood openings, but for carrying the railway over depressions in places where we should use an ordinary embankment. Such timber viaducts are however, looked upon as a temporary expedient, and when the timber shows signs of decay they are filled in with earth and buried in the permanent embankment.

The American railway in the portion of the country referred to is constructed at a cost much below that of Australian railways, yet railway travelling is quite as comfortable, which is due mainly to the special design of the locomotive engines and rolling stock. The Pullman Cars on passenger trains; and the long covered

freight cars on goods trains; cylindrical wheel treads, running upon the flat top of the rails, which are not canted as with us; the easing of curves of small radius, by introducing a transition portion at each end, leading gradually to the straight line; the introduction of vertical curves in the hollows and summits of grade lines; all contribute to the efficiency and economy of the railway.

In the Eastern States there is a very decided improvement both in the character of the railway and in the safety appliances used. I doubt if there are any better railways than the New York Central and Hudson River Railway, or the Pennsylvania Railway, these companies pay the strictest attention to all those matters which affect the efficiency, safety, and economy of railway working. In regard to the interlocking of points and signals, I do not think we have much to learn from America, indeed I think they might introduce with advantage on the western lines, the system which has been introduced and perfected by our Railway Commissioners here. On the western lines of America there are no signals, excepting starting, and at points, and excepting at grade crossing, there is no interlocking whatever. In the eastern States on the other hand, the interlocking system has come into use and is being gradually extended. At the large terminal station of St. Louis, known as the Union Depôt, I saw a very fine example of the electro-pneumatic interlocking system which deals with the starting and arrival of trains of twenty-two railway companies. This is an elegant arrangement, but it is not a block system. There are some fine examples of terminal stations in the larger cities, such as St. Louis, Philadelphia, and New York, with large arched roofs, the platforms are however, only a few inches above rail level. The absence of raised platforms, and station buildings at intermediate stations, and at smaller towns is characteristic, but here the economy appears to have been carried too far.

In regard to Locomotive Engines we have had considerable experience in this country, but it would be doing the Americans an injustice if we were to take the recently imported Baldwin

engines as a fair sample of their practice. There is no doubt whatever, that the American locomotive, both in design and construction is well suited for the service it is required to perform. In America freight trains consisting of from fifty to seventy covered cars of from thirty to thirty-five feet long are hauled by two or more locomotives, generally of the consolidation class, consisting of four coupled axles and a single bogie truck, whereas in England, shorter trains of small open trucks, sometimes covered with tarpaulins, are hauled by a single engine. The difference in practice is due to the different conditions existing, one of which is the longer haulages necessary in America on a single line. I consider that the statement often made that the American engine hauls more than the English type is founded on a misconception, as by the universal use of bogie rolling stock in America a much smaller resistance is offered to the tractive force exerted by the engine, and experience in this country with English built engines compares favorably with American in haulage, and in fuel economy. I was much impressed with the statements made by many railway engineers in regard to the compound locomotive; the general impression being that it is the coming engine for heavy freight traffic. This subject is now receiving considerable attention both in America and Europe, and the experiments of Professors Storm, Bull, and Goss, the Baldwin and the Brooks Locomotive Company, all go to prove that where the work to be done is approximately constant, there is a decided economy in the compound locomotive.

The Pennsylvania Company have built at Altona four distinct types of the compound locomotives for experimental purposes and I hope to receive shortly the results which ought to demonstrate the saving or otherwise due to the compound principle. Messrs. Beyer and Peacock of Manchester have built a few compound locomotives for our railways, according to designs prepared by the Chief Mechanical Engineer, Mr. Thow. These engines are of the type known as the Von Borris or Worsdale, which appears to be most in favour also with the American engineers.

The ratio of high pressure to low pressure cylinder area is as 1 is to 2·2, whereas in the continuous expansion engine with four cylinders of the Vauclain type, and in many of the French engines, the ratio is as 1 is to 3. Some locomotive engineers still consider that the economy saved in fuel does not more than compensate for the additional complication and higher boiler pressure.

In regard to permanent way, the standard practice now consists of eighty feet lengths of rail with long angle fish plates at joints, and six bolts. Some of the rails weigh 100 lbs. per lineal yard on this railway. The formation is carefully graded and drained, and is six inches higher in the centre than at the sides, there is from twelve to eighteen inches of ballast under the sleepers, the bottom ballast consisting of broken stone of larger size than in the top ballast. The high speeds attained on this railway and the freedom from shocks and vibrations is due to the high character of the road, and the excellence of the locomotives and cars. The chemical composition of the steel used for the rails is for the 80 lbs. rail as follows :—

Carbon ...	...	from ·55 to ·6
Silicon ...	...	from ·15 to ·25
Manganese	...	from ·8 to 1
Sulphur not to exceed	...	·069
Phosphorus not to exceed	...	·060

The lighter weights have less, and the heavier weights more carbon than given in the above figures.

The drop test consists of a weight of 2,000 lbs. falling twenty feet and striking the rail which is supported on bearings three feet apart. Should fracture occur the portion in tension must show a minimum elongation of 5% or the lot of rails will be rejected.

The American engineers prefer axles both for engines and cars made of Lowmoor iron in preference to steel, but in this matter they differ from English and European engineers, and I think their practice is in error. They use chilled cast iron wheels for cars, and pay special attention to the material used and mode of manufacture.

In locomotive boilers they almost, without exception, punch and rime the rivet holes in steel plates, and never drill unless specially asked for. In the Union Iron Works, San Francisco, I saw some large marine boilers in course of construction, but here the holes were drilled in position with horizontal drilling machines of special design. In the works of Messrs. Dübs & Co. of Glasgow I saw an excellent machine for drilling holes in boilers in which the drills are arranged normally to the shell of the boiler, and produce most perfect work. At Beyer and Peacock's works I saw a good drilling machine for boiler work which travelled horizontally along the flat plate, before it was bent into shape.

The out put of steel rails at the Edgar Thompson Works at Pittsburg probably exceeds that of any rail works in the world. At the Homestead Works the armour plate machinery can handle a fifty ton plate of nickel steel which is forged under a 10,000 tons forging press. Electric cranes transfer the armour plates from the furnaces to the press. Electric trolly cars convey steel blooms from a roller conveying-table in front of a train of rolls, to an electric charging machine in front of a re-heating furnace. The trolly car is provided with a motor and controller, and a man operates the charging machine while riding on it by means of electric switches, the same man telegraphs to the trolly car all the motions for it to perform, which are accomplished apparently without human agency. The laboratory in these works contains in addition to the ordinary testing appliances a special apparatus for investigating the microscopical structure of steel. In Professor Martin's laboratory at Berlin I also saw an apparatus of this description. In the Bethlehem Steel works the hydraulic forging press has a capacity of 14,000 tons, which is supplied with power rom the largest set of engines in the world. In Bethlehem and Pittsburg I saw the Harvey furnaces for producing a hard surface on the armour plates, and also saw similar apparatus at Messrs. Vickers' works, Sheffield, and at Herr Krupp's, Essen. The two latter works undoubtedly produce the best railway tyres and axles, which is largely due to the care exercised in the first instance

in using nothing but the purest materials available, to the method of casting the ingots with a head which is cut off, and the special machinery used to finish the axle or tyre which ensures that the material is practically homogeneous throughout.

Herr Friedrich Krupp uses nickel steel for propellor shafts and sometimes for crank axles which has a tensile strength and toughness far above the ordinary Siemens-Martin steel. The Krupp Works employs 29,000 men. The large steel castings produced at these works are extraordinary, and they have no rival in this department. The Dorman Long Works in Middlesborough are famous for their rolled girders, which are made of Siemens-Martin steel. Cochranes Works are noted for the excellence of their pipe castings. I visited the Hunt System of coal handling by machinery, for unloading vessels and conveying the coal by means of automatic railways to the coal pockets, where it is stored at a cost of about $\frac{1}{13}$ that of the ordinary methods using hand labour.

Bridge Work.

The Americans have distinguished themselves in developing a distinct type of bridge building, and generally their constructive work in connection with high buildings is worthy of careful consideration. The skill which they undoubtedly possess in this class of work has been developed in consequence of the existence of large rivers necessitating large bridges. In this country we have the Hawkesbury Bridge as an example of American design for railway bridges, and at Nowra there is an example of a road bridge. As illustrating the present practice of bridge building in America, I cannot do better than describe a few of the more recent bridges built or in course of construction.

The new bridge over the Allegheny River which connects Pittsburg and Allegheny by the main thoroughfare known as Sixth Street, was designed by Mr. Theodore Cooper, who is well known to bridge engineers as the author of the concentrated load system for the determination of the maximum stresses in railway bridges, and also for his complete specifications to govern the design of road and railway bridges. The contract for the masonry

was given to the Drake and Stratton Company, and for the superstructure to the Union Bridge Company. The two main spans of this bridge are 439′ 3″ measured between the centres of the end pins, it is of the bowstring type 79′ deep in the centre and spaced 44′ 6″ apart centre to centre. The panel lengths are each 29′ 3″. The floor is designed to carry a live load of 100 lbs. per square foot, or thirty tons on two pairs of wheels 10′ apart. The main trusses are proportioned for a moving load of 80 lbs. per square foot of floor surface, 40 lbs. per square foot of side walk, and 130 lbs. per square foot of roadway. The lateral and sway bracing is proportioned for 250 lbs. per lineal foot of span. The range of temperature allowed for is ± 75° F., and the maximum stresses in the various members are in accordance with the allowed stresses given in Mr. Cooper's specification of highway bridges. The masonry of the piers consist of rock-ranged work with rubble backing. In this bridge there was no attempt to go down to rock either by excavation or driving piles, as it was about sixty feet below the bed of the river, but it was necessary to found the piers below the reach of scour, on the firm gravel bed which exists for many feet in depth, and which was considered sufficient for sustaining the weight of the piers without piling. An open cofferdam was used built on the timber grillage, which forms the footing courses of the pier, and the bottom was simply dredged out.

In New York I inspected a large number of bridges in course of construction and completed, in company with Professor W. H. Burr and Mr. Hutton, and inspected many drawings in the New York Central and Hudson River Railway Company's office with Mr. W. Katte. I also had a number of interviews with Mr. Theodore Cooper, Mr. L. L. Buck, Mr. C. MacDonald and many other prominent men in bridge engineering, and I am indebted to these gentlemen for the valuable information I received, and for their uniform kindness in providing me with drawings and assisting me in the study of their works. I will direct your attention to a few of the more interesting of the bridges :—The Park Avenue Improvements, at the time of my visit in course of construction,

consist of an extension of the elevated railroad, and the construction of a large bridge having two fixed and one draw span over the Harlem River at New York. The draw span is 389′ long, measured between the centres of the end connections, and is formed with three main trusses arranged to carry four railway tracks, the depth of these trusses is 64′ over the central pier, about which they revolve; the opening and closing of the bridge being operated by steam power. The side trusses are designed for a dead load of 2,340 lbs. per lineal foot, and the centre truss for a load of 4,520 lbs. per lineal foot. The live load provided for is 3,000 lbs. per lineal foot per track, with an engine excess of 8,000 lbs. per foot on forty feet. The arrangements for distributing the load over the circular steel drum, which is supported on a double ring of live rollers, is worthy of notice, and is effected by means of a complete system of distributing girders. The fender for protecting the pivot pier is constructed of timber and thoroughly cross-braced, the space inside being filled with loose stone, it is 503′ long and 63′ wide. The two fixed spans present the usual characteristic features of American practice in trusses.

The elevated railroad forming the approaches to this bridge consists of spans of 65′ $2\frac{1}{4}$″ and are formed with three plate web girders 7′ 2″ deep, carrying four tracks. There is a continuous floor over these bridges and approaches, formed with steel troughing 18″ deep built of steel plates and angles $\frac{7}{16}$″ thick. The plate web girders on the sides have a top and bottom flange section in the centre consisting of two plates 20″ × $\frac{3}{4}$″ and angles 8″ × 6″ × $\frac{3}{4}$″; in the central girders there are three flange plates 24″ × $\frac{7}{8}$″ with similar angles. The web plates are $\frac{3}{8}$″ and $\frac{7}{16}$″ thick at the ends respectively. The web is united to the flanges by a double row of rivets through the angles, and the stiffeners and splice joints, are made with a much larger rivet area than is usual in British practice. The steel columns which support the ends of the plate web girders, are built up of angles and plates arranged with a trough section, and stand on broad bases.

I am indebted to Prof. W. H. Burr, for the complete set of drawings exhibited of one of his draw bridges, which is built over the Harlem River Ship Canal, and provides two clear openings of 104′ each; also, to Mr. Theodore Cooper for the view of the drawbridge designed by him for the Suburban Rapid Transit Company over the Harlem River. I have described and discussed these bridges mainly for the benefit of the Roads and Bridges Department and others who may have to design draw bridges, because I consider that in this direction there is much to be learnt from America, and our own practice may be very greatly improved. I saw nothing in England or Europe to compare with the bridges mentioned, and the more recent bridges such as those over the Manchester Ship Canal are decidedly inferior.

There is a great bridge under discussion at the present time in New York which is proposed for crossing the Hudson River between Fifty-ninth and Sixtieth Street. The total distance to be bridged is 3,200′ and two designs have been submitted by Mr. Charles McDonald which possess considerable merit, viz., a cantilever bridge with a central span of 202′ and a suspension bridge of 311′ span. Each of the main piers of the cantilever bridge which are two in number, are built of steel, having four main members rising in parabolic curves from its bases, each of which form a square in plan measuring 200′ on each side, up to another square of 80′ side. The bases at each of the four corners rest on cones, which are carried by four steel tubes, each 80′ in diameter, sunk in the bed of the river to a depth of 210′ below high water and filled with concrete. The section of the tubes forming the piers is of box section 15′ square, the height of the pier is 536′ above high water and the top of the supporting cone is 30′ above high water. From the piers the main span starts, and in three equal bays covers a space of 2,300′ between centres of towers. The headway is 150′ above high water. The floor of the bridge is curved to a parabolic form in a horizontal plane, and is 140′ wide at piers, and 80′ in the centre. The upper tension members are parallel throughout. The central truss carried by the canti-

levers is 720′ long and 160′ deep. The trusses spanning the shore intervals, each of 910′ in length, are not heavy enough to balance the weight of the centre span, and the four abutment cylinders are hollow; the end of the shore trusses are to rest on rollers or some equivalent on the tops of these piers, and are to be held down by pig iron weights suspended from their ends and hanging within these piers, and representing an aggregate weight of about 14,000 tons. The floor of the bridge will accomodate six railway tracks.

The suspension bridge proposed consists of steel towers 557′ in height, resting upon foundations of solid masonry extending to a depth of 125′ below high water. The bridge will be 125′ wide, and will be suspended from twelve steel cables, with a clear headway for ship traffic of 150′. The cost of this bridge is guaranteed by the Union Bridge Company not to exceed £5,000,000. Mr. Theodore Cooper is the consulting engineer for this enormous structure and there are several points in his specification which are worthy of notice:—"The bridge will have six standard railway tracks upon one level. The general type of the proposed bridge will be a steel wire suspension bridge, stiffened for moving loads by longitudinal girders extending from tower to tower. The main span only, or that portion between the towers will be carried by the cables. The side spans or that portion between the towers and anchorages will be carried upon viaducts independent of the cables. The towers will be steel skeleton structures, commencing at an elevation about fifty feet above high water, where the masonry piers end. All the connections must be rivetted, and all the bracing must be rigid. The stiffening truss will be rivetted lattice girders, with multiple systems of diagonal web bracing. They may be continuous from tower to tower, or they may be made with a central hinge at the option of the contractor." The dead load will consist of the weight of metal in the structure, and the weight of rails, ties, guards, footwalks etc., above the longitudinal track girders shall be taken as 400 lbs. per lineal foot per track. The live load shall consist of trains weighing 3,000 lbs.

per foot run per track, covering all tracks from tower to tower at rest or moving slowly. Trains 1,000′ long weighing 3,000 lbs. per track, at high speed enter all in one direction or in different directions, three on the north tracks and three on the south.

For wind stresses, the structure is supposed to be covered with trains of cars, and acted upon with 25 lbs. per square foot of surface; or a wind pressure of 100 lbs. per square foot of bridge for a length of 300′ only. The allowed stresses are as follows:—Cables in tension, 54,000 lbs. per square inch on the wires in the cables; suspenders, 30,000 lbs. per square inch in the wires; cross stays, 60,000 lbs. per square inch in the wires; anchor bars, 20,000 lbs. per square inch. Stiffening trusses—The chords of the stiffening trusses when subject to tension only, shall not be strained above 18,000 lbs. per square inch of net section for live loads or 22,500 lbs. by the combined action of live loads, temperature, and wind. Mr. Cooper gives special formulæ for the allowed stresses in other parts similar to those given in his standard specifications for steel bridges, also a formulæ for members subject to reversal of stresses by live loads.

Mr. L. L. Buck has in hand three very large bridges, and has completed the designs and commenced to build an arch bridge of 840′ span, with a central rise of 150′, giving a headway in the centre of 170′. This magnificent structure is now in course of erection across the Niagra Gorge, for the Niagra Falls and Clifton Suspension Bridge Company. The arch ribs are 26′ deep and are spaced 68′ 7″ apart at the springing, narrowing to 30′ in the centre. Mr. L. L. Buck has designed another arch bridge to replace the existing railroad suspension bridge at Niagra, and he is chief engineer for building the new East River bridge between New York and Brooklyn.

I met Sir J. Fowler and Sir B. Baker in England, and visited the great Forth Bridge. I also had several interviews with Sir W. Arrol, the contractor of the Forth, Tay, and Tower bridges.

In regard to bridge manufacture, the Pencoyd and Athens Bridge Works are well equipped with special machinery for

hydraulic forging of eyebars, boring holes for pins in bridge members; large milling machines with circular heads, provided with a number of cutters arranged circumferentially. These milling machines are used for facing the ends of long struts, and compression chord members producing parallel planes. There are special machines for milling the ends of angles and tees for stiffeners so that they fit into the rounds of the main angles. Electric and other cranes are so disposed that they can handle rapidly the material used; or the partly finished member, and transfer it to the various machines. In the American works they generally punch the holes for rivet work, but when these are drilled, radial drilling machines are preferred to multiple drilling machines. I saw an excellent multiple punching machine in the Athens Works with an automatic feed. In Sir Wm. Arrol's Works, Glasgow, the general practice is to drill all holes, excepting in cylinder piers, and they use radial drilling machines for this work, but there are in these works some special drilling machines of a most interesting character, which were specially made for dealing with the Forth bridge work. In the Harkort Works, Germany, they punch or drill the holes for bridge work according to instructions.

In San Francisco I saw a very extensive pile and concrete foundation in course of construction for the Union Depôt Ferry House, forming the approach to ferry slips on the water front. This piece of concrete, pile and grillage work is probably the largest in the world of its kind, and involved the use of 30,000 cubic yards of concrete, in which 36,000 barrels of cement were used; 3,000 old piles were removed and 5,000 new ones substituted. The piles were of oregon timber 80′ long, and when these were driven to the proper depth, by means of a steam hammer, they were all cut off to the necessary level for the grillage upon which the concrete piers were built. A circular saw was used for cutting off the tops of the piles about 8′ below low water. The saw worked in a horizontal plane, and was carried by a frame which swung on a vertical axis; the arc of the circle described by the

centre of the saw was 9′ radius. The concrete was deposited in caissons, the bottom of which formed the permanent grillage, the sides were removed after the concrete was set and used over again. The concrete was composed of one barrel of cement to six cubic feet of sand and twenty-four cubic feet of broken stone.

An interesting case of cheap dredging occurs at Liverpool, which has been undertaken by Mr. A. G. Lyster to improve the entrance to the river Mersey, so that vessels coming from America may not be delayed in consequence of the insufficient depth of water over the bar. Formerly vessels could only enter during the period of about two and a half hours, about high water. The dredge used for this purpose is of exceptional dimensions, being 320′ long by 46′ beam, and having a draught when fully loaded with 3,000 tons of sand of 16½′. The suction pipes which are two in number, are placed in the forward part of the ship, and the suction pipe which is 45′ in diameter is trailed aft through a well on the centre line of the ship. At its upper end it is fitted with a trunnion joint at the point where it branches off to the sand pumps, and below that again with a universal joint. The pipe is long enough to enable the vessel to dredge to a depth of 47′ measured from the surface of the water to the surface of the sand. The hoppers for the reception of the sand are eight in number, placed on each side of the well referred to. Instead of the usual hopper doors for the discharge of the sand, a 4′ hole is constructed at the bottom of each hopper, which is covered by a cylindrical valve extending to the top of the hopper, where its diameter is somewhat greater than at the lower end. The valve, which is cased in at the upper and lower ends, is connected by a sliding pipe with the discharge from the circulating pumps, and when lifted, which is done by a hydraulic ram and cylinder, the water is turned on and is discharged through holes on the lower periphery of the valve, thus breaking up the sand and forcing it out through the hole in the hopper. By this means 3,000 tons of sand can be discharged in ten minutes. The sand pumps can dredge about 400 tons an hour, and the cost of dredging is 0·89 d. per ton repre-

senting from $1\frac{1}{2}$ to $1\frac{3}{4}$ cubic yards. The cost included the removal of the deposit a distance of three miles to the dumping ground.

In Glasgow I saw the various dock works in course of construction by the Clyde Navigation Trust. The foundations upon which the dock walls are built, consist of concrete cylinders which are arranged in three rows. The rings are made each 2′ $5\frac{1}{2}$″ deep and are 1′ 11″ thick with an internal core of 5′ $9\frac{1}{2}$″ diameter. The rings are moulded separately in wooden moulds, and the cylinders are made to break bond, and are dovetailed into each other. The cylinders are sunk by loading with cast iron rings, and excavated from the inside by means of grab-diggers. A casting with a cutting edge is bolted to the bottom course to facilitate sinking. After the cylinders have been sunk to a proper foundation, the core is filled with concrete and the dock wall is built up of concrete rubble, many of the stones used weighing from two to three tons each. The fall is faced with concrete ashlar in courses 18″ to 15″ thick with a granite coping. A single row of triple cylinders makes a wall of 16′ $3\frac{1}{2}$″ wide. I am indebted to the chief engineer Mr. James Deas for the following particulars of the cost of this work:—Excavating high ground and depositing in water space, 7d. per cubic yard. Excavating in sinking cylinders and depositing in water space 1s. per cubic yard. Filling in cylinders with concrete eight to one in lower part and nine to one in upper part 10s. 6d. per cubic yard. Moulded concrete ashlar blocks including facing with granulite, and setting in work 11d. per cubic foot. Concrete rubble backing 10s. per cubic yard. Dredging out water space and depositing by hopper barges in Loch Losy, 6d. per cubic yard.

In Glasgow, Sir Wm. Arrol was good enough to show me the various works in progress in connection with the underground railway and subway, which involves a very entensive system of underpinning the foundations of the houses on each side of the street, under which the railway has been constructed and getting in the side walls and girders without interfering with the ordinary street traffic. I also saw the rebuilding of one of the

Telford Bridges over the Clyde in which the cylinder piers were being sunk on the pneumatic process with an air-lock. The Blackwall Tunnel is a fine example of compressed air work which is now being employed in a similar work at New York, consisting of a tunnel under the Hudson River.

Economical Generation, Transmission, and Utilization of Electricity for Power Purposes.

I propose to describe to you, briefly, a few of the most important developments in this branch of Engineering. In America, more especially, I was much impressed with the extensive use made of electricity, for working street railways, for machinery in workshops usually driven by steam power, and also for working cranes, hoisting and pumping machinery. With some exceptions, a few of which I will consider presently, the energy for producing the electricity is derived from burning coal and generating steam by means of boilers and engines driving electrical generators.

The chief use of electricity in connection with the development and transmission of power is at present best seen in the Electrical Railways of America, England and Europe, and these are nowhere better illustrated than in America, where almost every town is provided with an electric tramway running through its principal streets, and extending for many miles to the suburbs. The economy and convenience of this system is most satisfactory, and the benefits conferred upon the community in providing a cheap and elegant means of transportation can hardly be realized by those unacquainted with the system.

To give some idea of the extent of the Electric System in America, it was stated by the *Street Railway Journal* in October last, in connection with the Street Railway Convention at Montreal, at which I was present—"That 14,000 miles of Electric Railways were earning one third as much in net dividends as 234,000 miles of Railway." This remarkable statement means that the average net earnings per mile on the Electric Railway

was more than five times as great as on the railways worked by steam power.

San Francisco, which was one of the first cities to adopt Cable Tramways, is now provided with a considerable mileage of Electrical Street Railways. During the last year seventy miles of horse tramways have been converted to the electric system. San Francisco is preëminently a city of heavy grades, but these have been successfully dealt with on the Electric Railways, grades of one in twelve to one in eighteen being taken in the ordinary way with powerful motors on the cars, while a few short grades of one in four are dealt with on the balance weight system.

In Chicago, the Metropolitan West Side Elevated Electric Railway was opened last year, and the result was so satisfactory that the other elevated railway companies have decided to adopt electricity in place of the present steam locomotives. Chicago is well provided with street railways, but enormous extensions are contemplated on the electric system.

In New York, the elevated railways worked by steam, and the splendid cable tramway down the principal thoroughfare known as Broadway, deal with a considerable portion of the traffic in the direction of what may be called the length of the city, but the streets which run across are worked by horse and electric cars. It is proposed to dispense with the horse, in favor of electric cars, and to greatly extend the electric system in the city and suburbs.

In Boston, and in other large American cities, electricity bids fair to supersede every other mode of transport for street and suburban traffic.

Power Stations.—In some cases the engine is connected to the generator by means of a flexible spring coupling. The power houses of America contain some of the finest steam engine plants in the world. The most usual type of generator for street railway purposes is the direct current multipolar machine, which delivers a current at a pressure of about 500 volts. And when these are driven directly from the crank shaft of the engine the

speed is from seventy to one hundred revolutions per minute, but where the generator is driven by belting a much higher speed is usually adopted.

A reduction in speed must imply a reduction in weight if the same output and degree of general merit are to be obtained, and an increase in the first loss ; but this is compensated for by the losses of energy due to belting, the trouble saved in bearings, cost of maintenance, and other objectional features familiarly associated with belt driven generators. Each system has its advocates, but the direct driven generators appear to be in more general favor.

As an example of belt driven generators, one of the most modern plants occurs in the Power Station of the Hartford Street Railway, Conn. Here the engines are six in number, of the Ball and Wood type, working at a high speed and developing 300 H.P. Each engine is connected by belting to a generator of 220 K.W. capacity ; the distance from the centre of the fly-wheel to that of the generator pulley being twenty-five feet. The advantage of a large number of units is claimed to be, that with the varying loads existing in electric railway service, those engines which are in use can be operated at full load, and consequently at their greatest point of economy.

As an example of slow speed engines directly connected to generators of large capacity, we may take the Delaware Avenue Power Station of the People's Traction Company, Philadelphia. There are at present three engines, each of 2,000 H.P. of the twin compound tandem Corliss type, manufactured by Edward P. Allis Co., and the speed is sixty-seven revolutions per minute.

The generators are 1,500 K.W. capacity made by the General Electric Company, and the armatures are keyed to the crank shafts of the engine. An advantage claimed for this system, which consists in reducing the number of units and increasing their size, is that there are fewer units and fewer parts to look after, and consequently there is a reduction in the cost of maintenance—again the economy in using large engines of the Corliss type is well understood and appreciated.

The advantages of concentrating all the power required for a large city in a central power station employing large units was forcibly impressed upon me during my inspection of the most important power stations in America and Europe, as the primary object is the production of electrical energy at a minimum cost, having regard to interest on capital expended as well as maintenance. It should however, be borne in mind that where there are several long lines to be operated, the cost of copper in the conductors would be prohibitive if direct currents were used at a pressure of 500 volts. In such cases, the multiphase system of transmission, by means of alternating currents should be adopted, by means of which a sub-station may be operated economically twenty miles from the main generators in the power station. Examples of this will be given presently.

The transmission of the electric energy from the power station to the cars will now be considered. The system which is at present almost universally adopted is known as the Overhead Wire or Trolly System, which consists of poles on the sides or centre of the streets, the projecting brackets carrying the overhead or trolly wire over the centre of the track. The cables which convey the currents to the trolly wires may be laid underground, on the side poles, or on each side of the centre of the central poles. These are generally much more unsightly than they need be in America, but in Philadelphia and Buffalo, although not ornamental, they are by no means unsightly. The same may be said of Havre, Berlin, Brussels, Zürich, and in several other cities I visited.

The trolly wire is usually divided into sections, with a separate feeder to each to avoid inconvenience, as in the event of anything going wrong in a particular section the rest will be unaffected. The return current is conveyed by the rails, which must be suitably connected at the joints, or better, by means of an armoured copper wire between the rails and connected with them at intervals.

The Conduit System was proposed in order to avoid the unsightliness and obstruction caused by the Trolly system. It is

necessarily much more expensive than the Trolly system, as a subway or conduit has to be constructed, in which the conductors are placed. The conduit system in various forms has been tried with more or less success, among which may be mentioned Bently-Knight, Love-Connett, Wheless and the Buda Pesth. The system is open to the objection that dirt, snow, and water get down the conduit through the slot, and afford facilities for leakage from the conductor, but this does not apply to the closed conduit system such as that put down experimentally at Lyons and Washington.

The most promising conduit system is that which I saw working most successfully in Lennox Avenue, New York. The quiet and smooth running of the cars is most satisfactory. The conduit contains the conductors spaced six inches apart, and the difference in pressure in the two circuits is 350 volts. A plough connected with the motors on the car is pressed by means of a spring connection against the conductors, gathering current from the one and returning it to the other. No current passes through the rails or wheels. The conductors which are insulated by means of porcelain insulators consist of double channel iron bars four inches deep.

Another system which I saw working successfully in Washington, consisted of underground wires connected at intervals of about six feet with two rows of metallic disks. The cars carried scrapers which rubbed against the disks as the car passed over them. Switches are arranged in the conduit and a storage battery in the car, the only function of which is to magnetize the moving scrapers on the car, so that they always touch the disks, and thus actuating the switches they enable the motors in the car to derive their supply from the feeders in the conduit. The current is thus supplied through the disks and scrapers at intervals of about six feet. The system so far is experimental, but I saw it working well in Washington, and it may be considerably extended.

I saw two other systems; one at the General Electrical Company's works in Schemcktardy, and another at Siemens-

Holske works in Berlin, very similar to the last described, but still in the experimental stage. It is clear, therefore, that there is a general effort being made to find something better than the overhead wire and more in accordance with our notions of a permanent system, providing ample security against injury, but this cannot be done without increasing considerably the cost of electrical transmission.

Motors.—An electric motor for street railway service differs from an ordinary electric motor for driving shafting, in that the power to be overcome is very variable. The large torque, or starting power, is the characteristic feature of the street railway motor, and it has been found that the average work is about 20% of the maximum which occurs at starting. The electric motor has no dead centres like the steam engine, and can start equally well in all positions of the revolution.

Electric motors must be light and strong, must be completely protected from dirt and water; they should be capable of developing an emergency 100% more than their rated capacity without undue heating. All parts should be accessible and easily taken apart, and renewed or repaired when necessary. Motors are general series wound. The pole pieces are steel castings of a specially soft quality of metal, and in order to prevent losses from hysteresis, eddy currents, and friction, as well as to produce the large torque, a large number of windings of wire in the armature are necessary. A spur pinion on the motor drives a spur wheel on the axle, the reduction in speed is about one-fourth, and these are made with the greatest accuracy, by means of automatic wheel-cutting machinery. The armature is built up of a core consisting of thin soft iron disks, and these are punched out all round their circumference into notches, which form the slots for receiving the coils or winding, after the disks have been threaded upon the axle or shaft of the armature, and compressed by hydraulic machinery. The coils are made up separately, being wound into form, carefully bound with several layers of insulating material and treated with insulating compound. The completed

armature revolves within one tenth of an inch of the poles of the magnet.

Controller—To apply the current from the line wire to the motor, so that the car may be stopped, started, reversed, and for regulating the speed, it is first passed through a special form of compound switch called a controller, which consists of a cylinder with metallic strips or contact pieces fixed as arcs upon its surface. The necessary connections are thus made as the cylinder is revolved by means of a handle which corresponds to both regulator and notching up lever in the locomotive engine.

If the full pressure of 500 volts were suddenly applied to the motors in a car, the cars would start so suddenly that the passengers would be injured, so that it is necessary to temper the pressure at starting, and apply to each motor less than half the total voltage, gradually increasing the pressure and thereby the speed of the car, until the maximum is reached.

The General Electrical Company recommend their Series Parallel Controller in preference to the rheostatic method of control, and in order to start the car the motors are first connected in "series," *i.e.*, the circuit passes first through one motor and then the other without division. By this means (together with a very slight resistance which is instantly cut out) the proper starting pressure is applied without loss, and the motor being in series, the same current that starts one flows through the other. After the car is started the voltage applied to each motor is increased by gradually throwing the motors into "parallel," *i.e.*, the circuit is divided, one branch passing through each motor. At full speed the motors are in parallel with no resistance in the circuit.

The changes from series to parallel necessitate the breaking of heavy currents at a high potential in a limited space, and the sparks or arcs produced would destroy the contact plates, fingers, cylinder, and all parts in the vicinity of the break; but the cylinder is embraced by a powerful magnet, which blows out the sparks immediately they tend to form.

Switches are arranged at the foot of the controlling cylinder so that either motor may be thrown out of the circuit, the throwing of either switch sets a stop automatically preventing the turning of the cylinder beyond the proper limit. The setting of the reversing handle indicates which way the car will move, but this cannot be moved until the power cylinder is thrown off, so that the car cannot be reversed at full speed. A dial on the cap plate indicates at what point the connections of the cylinder are set.

Brakes.—Electric cars should be provided with an efficient brake for stopping them quickly whenever necessary.

While attending the Street Railway Convention at Montreal, I had an opportunity of studying what appeared to be a most efficient form of electric brake, which is used in conjunction with the Series Parallel Controller just described, it is operated by throwing the controller handle into the breaking position, which converts the motors into special dynamos for generating current at very low speeds, cuts off all connection with the trolly current and applies the brakes. The rheostats and contacts employed to control the motors while running the car, are also employed to control the current generated by the motors, which is needed to apply the brake. The power required therefore to perform the work of stopping the car is taken from the energy of the moving car itself, which it is the function of the brake to destroy. Not only is the car thus retarded, but the electric brakes arrest the motion of the wheels direct, with a force which is remarkably powerful and under perfect control of the motor man.

Another very satisfactory brake is that made by the Standard Air Brake Company, which is of the compressed air non-automatic type, and it is used by the Railway Commission here in Sydney for street cars.

As to the cost of working Electrical Tramways as compared with Cable Tramways :—

The cable tramway for very heavy traffic on a straight, or moderately straight line, is at present more economical than the

electric tramway, but generally speaking the electric is more economical than the cable.

In Chicago, where there is an excellent cable as well as an electric service, the cost per car mile was fivepence with the cable, as against eightpence with the electric, but the receipts were tenpence with the cable against seventeenpence with the electric. Hence the profits derived from electric traction are much greater in Chicago than with cable traction.

In Sydney if the work of converting our present system of tramways is done as well as we have a right to expect it to be, we shall have no reason to regret the change financially. In every other respect the result is likely to be beneficial, and I wish the Railway Commissioners every success in their endeavours to provide a complete system of electric tramways which will meet the wants of Sydney.

Electric Locomotives.—The largest electric locomotive yet constructed in America is that which is used for working the Baltimore Belt Line, which consists largely of tunnels. Electricity was adopted in this case to avoid fouling the tunnels with smoke and burnt gases. This involved the construction of three ninety-five ton locomotives, each capable of hauling a five hundred ton passenger train at thirty miles an hour or a 1,200 ton freight train at fifteen miles an hour on a gradient of one in one hundred and twenty-five. The locomotives are now in actual service, and are working in a satisfactory manner; they will exert a draw-bar pull of 42,000 pounds continuously, or 60,000 pounds at starting, and they are said to be capable of developing 1,400 H.P.

I saw the large electric locomotive constructed by the Westinghouse and Baldwin Locomotive Company standing in the Baldwin Works, Philadelphia, and during my visit to the General Electrical Company's Works at Schenecktady, I saw a still more powerful locomotive in course of construction, with larger driving wheels for higher speed. So far however, it appears that while electric traction may be used with economical results in street and

suburban railways, it is not likely to supersede the steam locomotive for ordinary railway traffic on long distances.

I have no time to consider the method of traction by means of storage batteries carried by the car itself, but so far, this has not been very successful. Of course if a cheap storage battery could be made suitable in every respect for railway traffic, it might alter considerably our present notions of electric transmission. Time will not permit me to refer to the elevated railways worked by electricity.

Electricity has been largely used for the distribution of power in workshops—among which may be mentioned the works of the General Electric Company, and the magnificent works at Pittsburg recently built by the Westinghouse Company, also the Baldwin Locomotive Works at Philadelphia; the Brooks Locomotive Works, Dunkirk; the works of Fried. Krupp, Essen, Messrs. Siemens-Holske, Berlin, and many others. It has been demonstrated in many cases that this method is most economical, as well as having many advantages over the usual methods where a series of shafts, counter-shafts, and belting are employed. Experience has taught, that in shops where both large and small machinery is used, it is economy to operate each large machine with a separate motor, and to group the smaller machines in sections, driving each section with a motor.

The principal saving in power realized by the electric system of distribution is due to the fact that when a machine is stopped, the power required to drive it stops at the generator, and not simply at the machine itself, as in the case when driven by a system of shafting. Further, when the load is reduced, the loss in line wire between generator and motor is reduced directly in proportion to the reduction of current consumed by the motor. This regulation is instantaneous, and at any time the dynamo only generates as much current as is needed by the motors at that particular time.

The large engine, upon the crank shaft of which the armature of the multipolar generator is fixed, is far more economical than

the small vertical engines which are usually used for a section of shafting. The electric motors work at about 90% efficiency, and the loss in the short line wire between them and the main generator is comparatively trifling.

The General Electric Company have constructed several installations of electrical underground haulage plants for collieries, and I saw an excellent plant at work in San Francisco, for hoisting coal from ships and afterwards hauling it on a short electrical railway.

Electric motors are employed to drive fans, centrifugal and other pumps, air compressors, and for a great variety of purposes.

I will now briefly consider the generation of electricity by means of water power, and its transmission to long distances. There are many places where nature has provided large supplies of energy in the form of falling water, and to convey this energy to points where it may be utilized in an economical manner is a problem of vast importance. The principal methols available for transmitting this power are :—Hydraulic Transmission, Pneumatic Transmission, and Electric Transmission. Which of these methods should be adopted for any given case will depend upon prevailing conditions and requirements. Except for very short distances however, electric transmission has no rival in point of economy, flexibility, efficiency, or general utility.

The distance over which power can be transmitted electrically depends primarily upon the electro-motive force that may be safely and judiciously employed, and when it is considered that for a given electro-motive force the cost in copper conductors increases directly, as the square of the distance, it follows that the cost of conductors will be an important factor in the financial success of any scheme which the power is generated at a considerable distance from the motors utilizing it. But the amount of copper in any conductor is inversely proportionate to the square of the electro-motive force—that is to say, if the distance and other conditions, except the electro-motive force be fixed, it will

require one-fourth as much copper to transmit a certain amount of energy if 2,000 volts be used, as will be required to transmit the same energy with equal efficiency over the same distance if 1,000 volts be employed. And it will require $\frac{1}{100}$ as much copper if 10,000 volts be used as will be necessary if the potential is limited to 1,000 volts. Hence the necessity of using high voltages in long distance transmissions, and this is most economically accomplished by the use of alternate current generators and transformers. The great advantage of the alternating current generators over the direct current generators is that no commutator is necessary. That part of a direct current machine which is especially liable to cause trouble when high potentials are employed is the commutator, which is of all essential elements of a generator or motor the most complex and expensive, while it is at the same time the most delicate and liable to damage. Again, in the alternating current machine, the manner of placing the wires on the armature admits of better protection, more thorough insulation, and greater facility of repair, since one wire is wound continuously and there is no exposed part, except the collector rings to which ends of the wire are connected. The necessity of breaking the windings of a direct current machine into so many parts makes thorough insulation of the armature very difficult.

The Westinghouse Company have developed two distinct systems for transmitting alternative currents, viz., the synchronous or two wire alternating current system, and the Tesla polyphase or multiphase system.

In the two wire synchronous system the generator and motor are connected with two wires, and but one current flows between them. In the polyphase system the generator and motor are connected with three or more wires, and two or more currents differing in their time relation or phase traverse the wires.

In the two wire system the number of alternations which are employed is about 7,200 per minute; in the multiphase system a lower number is adopted. The two wire systems are not self-

starting, a small auxiliary motor being used to bring the large motor up to its proper speed, before the load is thrown on; the multiphase starts with strong torque and requires no auxiliary starting device. The General Electric Company use a three phase transmission system where power is required to be conveyed a long distance. The electric power generation at Niagara, furnishes the most modern, and at the same time the most gigantic example of the utilization of water power. The works at Niagara comprise—(1) a head race canal 200 feet wide, 1,500 feet long, and seventeen feet deep; (2) a great Tunnel race 700 feet long, twenty-one feet high, eighteen feet ten inches wide, with a slope of from four to seven feet per thousand, to discharge the tail water of the turbines into the river below the falls; (3) works for the distribution of water to large consumers who erect their own machinery with lateral tunnels to discharge their water into the tail race tunnel. The Niagara Falls Paper Company have contracted to take 3,300 H.P. and the right of taking as much more subsequently. The Pittsburg Reduction Company, who control the patents for the production of Aluminium electrically, have acquired the the right to use 6,000 H.P. and have built works. I saw the large electric machines for these works in course of construction at the Pittsburg Works. (4) A large power station has been built and partially fitted with machinery for generating electricity for Niagara and Buffalo and perhaps beyond. This power house is placed alongside the head race canal, and is designed to contain ten turbines, each of 5,000 H.P. Several of these generators are now working, and others I saw under construction at the Pittsburg Works. A wheel pit or slot has been sunk, which is at present 140 feet in length, twenty-one feet in width, and 170 feet in depth, having room for four turbines. It will be extended as required. Over this the first section of the power house has been erected.

The turbines for the power station are 5,000 H.P., running at 250 revolutions per minute and are placed at the bottom of the wheel pit 175 feet in depth, and transmit their power to the

generators by means of vertical shafts. The turbines were made by Messrs. Faisch of Switzerland. The electrical generators are of the Tesla polyphase alternating current type. Each generator delivers an alternating current to each of two circuits, the currents in these circuits differing from each other in their time relation or phase by 90°, that is to say, the current delivered to each circuit attains its maximum value at the instant when the current delivered to the other circuit is zero. The frequency is twenty-five cycles per second, in other words the current is reversed 3,000 times per minute. By means of rheostats controlling the field circuits of the generators the potential of the current delivered is adjusted up to the limit 2,400 volts.

The currents delivered by the generators are conveyed through heavily insulated cables to the switch board, there by means of suitable switching devices the engineer in charge can connect any one of the generators, or any combination of them to the external circuits which convey the current from the power house to the consumers. Currents intended for transmission to considerable distances, as for example to Buffalo, will pass from the switch-board through similar lead covered cables in the power house subway and the bridge to the transformer house. There it is proposed to transform the current up to 20,000 volts. At the distant end of the circuit stepdown transformers will be used to reduce the potential to an amount suitable for local requirements.

In the case of large motors used in Niagara, the current will be probably supplied at the voltage delivered by the machines without transformers, but for smaller motors and where direct currents are required stepdown transformers must be used. The Niagara generators represent the highest state of the art of design and construction of electrical machinery. The revolving parts consist of the vertical axis of the turbine shafts, which are twelve inches in diameter ; the armature is stationary, but the field ring carrying the field magnets is suspended from the top of the vertical shafts and revolves with it. The field ring is made of nickel steel of very high quality, having a tensile strength of

82,000 pounds per square inch and 25% elongation; this was made by the Bethlehem Steel Works and expanded from a solid ingot of compressed steel. The vertical shaft is made of open hearth steel.

Niagara will ultimately become in my opinion a great industrial centre distributing the enormous energy derived from the Falls to the various works around it, and is a fine example of the utilization and control of one of the great sources of power in nature, for the use and convenience of man.

The General Electric Company of America have designed and constructed a large number of long distance power transmission plants, one of the most important of which is that at Fulsom, on the American River, twenty miles above Sacramento; a water power has been developed by the construction of a dam and canal. In the power house is installed four 1,200 H.P. horizontal turbines working under a head of fifty-five feet. Coupled to these wheels are four 750 K.W. three phase generators which run at a speed of 300 revolutions per minute, and furnish current at a pressure of 800 volts, and a periodicity of sixty cycles per second. The potential is raised to 11,000 volts by 250 K.W. transformers, located in the second story of the power house. There are two complete pole lines carrying transmission lines of over 90% efficiency from Fulsom to Sacramento, where the potential is reduced for distribution. In the sub-station there are three 300 H.P. sychronous motors which drive a line of shafting to which is belted the generators for supplying the electric tramways in Sacramento, and for electric lighting. These generators are 475 K.W. capacity and capable of supplying 300 lights. Being a three phase system there are three copper wires conveying the current from Fulsom to Sacramento and at Sacramento a low pressure network on the Edison three wire system is fed from the transformers to the sub-station feeder regulators giving complete control of the potential on the lines.

THE MACHINERY EMPLOYED FOR ARTIFICAL REFRIGERATION AND ICE MAKING.

By NORMAN SELFE, M. Inst. C.E., M.I.M.E., &c.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, July 15, 1896.*]

OWING to the very great increase, which has lately come about in the exportation of our food products to Europe, few branches of mechanical engineering are of so much importance to Australian trade as the design and construction of the machinery used for producing low temperatures, popularly known as "Freezing Machines."

HISTORICAL.

Over three hundred years are supposed to have elapsed since it was first discovered that artificial cold is produced by the chemical action which takes place when certain salts are dissolved, but it is not known how far back the system of making ice has been practised which is still in use in India, where shallow trays of porous material are filled with water and exposed to the night air, when the heat is abstracted by natural evaporation. The use of frigorific mixtures for the abstraction of heat (many forms of which are still set out in works on chemistry) was known as far back as the year 1607, and the most common combination, that of ice and salt (which is said to have been used by Fahrenheit in 1762, when he placed the freezing point of water at 32° as the limit of negative temperature) is still in every day use for such purposes as ice cream freezing. The production of cold by what may be termed mechanical means—that is by the use of a refrigerating machine, as distinguished from chemical action—is of much more recent date. A Dr. Cullen is said to have made a machine for evaporating water under a vacuum in 1755, and Lavoisier experimented with ether in France, but the next important steps appear to come well into the present century. In the year 1810,

Leslie experimented with a machine using sulphuric acid and water. In 1824 a machine was patented by Vallance, who probably got his idea from the evaporative system so long in use in India. Under this patent, dry air was circulated over shallow traysof water when evaporation took place and heat was abstracted.

In 1858, Mr. George Bevan Sloper patented a similar system in this Colony,[1] under which the water was exposed in canvas bags so that the whole surface of the containing vessels was open to evaporation as well as the surface of the water itself. The machine to work this process was designed by the author, to carry out the ideas of the patentee thirty-eight years ago, and it was constructed in Sydney by Messrs. P. N. Russell & Co., and tried in Margaret Street. No commercial success however did, or could attend any such system of producing artificial cold owing to the excessive amount of power required to produce a given result, and in this particular case, as the air delivered into the chamber under partial vacuum was not made to perform work, it did not part with its heat and reduce the temperature of the water as it might have been made to do had the knowledge of thermo-dynamics been then as widely extended as it now is. In 1834 Hagen used the volatile spirit of caoutchouc, and in the same year Jacob Perkins, of London, constructed what appears to have been the first ice making machine which really worked successfully with a volatile liquid. In this machine ether was vaporised and expanded under the reduced pressure maintained by the suction of a pump, and the heat abstracted from the substance to be cooled, the resulting vapour was compressed by the same pump into a vessel cooled by water until liquefaction of the medium again resulted as the vapour parted with heat to the condensing water under the influence of the increased pressure. The liquefied medium was then ready to be evaporated and expanded over again.

Fig. 1 is taken from Perkins' English patent, No. 6662 of Aug. 1834, and shews clearly that his invention included the four

[1] N. S. W. L. R., No. 14, 1858.

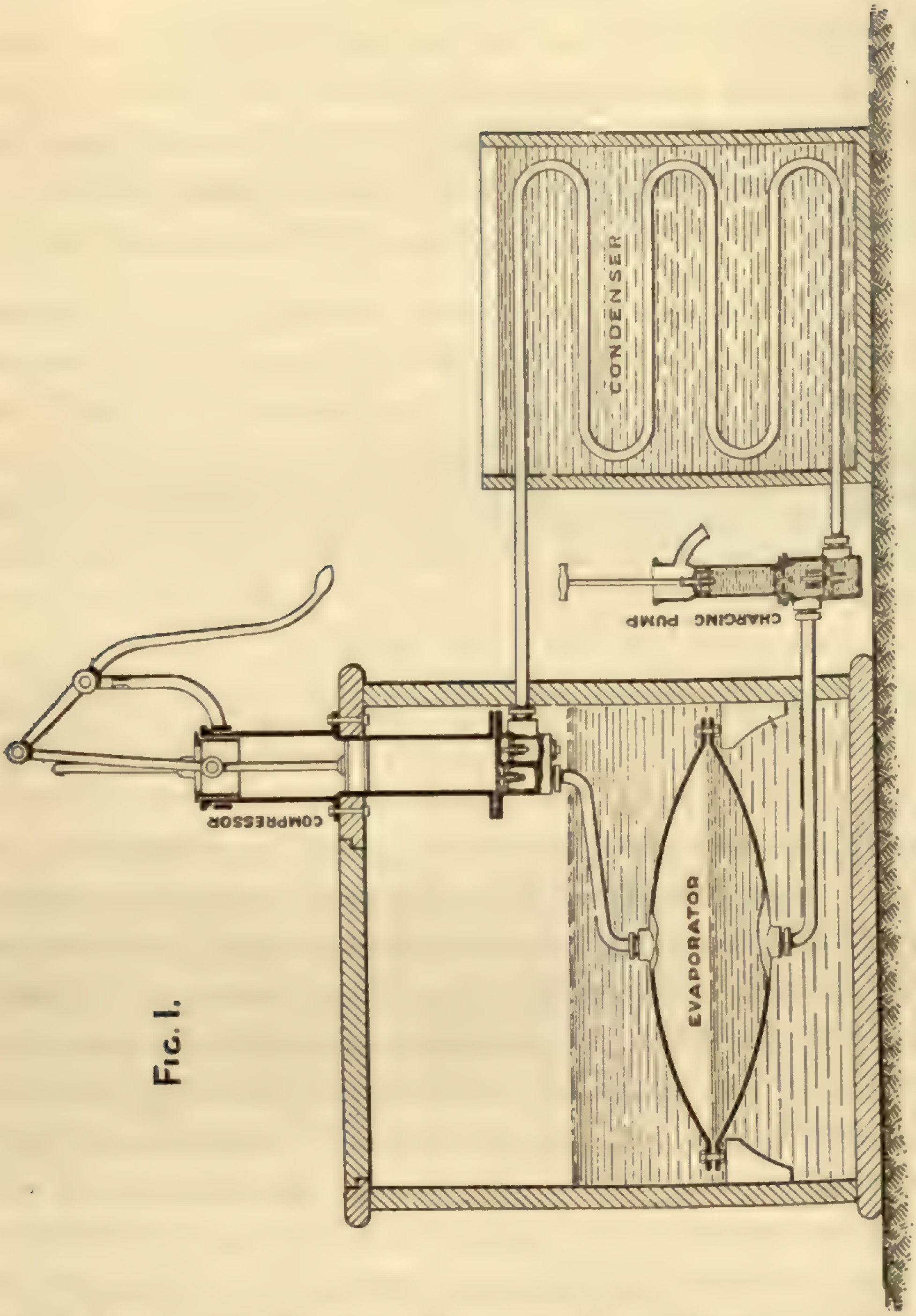

FIG. 1.

NOTE.—The Valve which regulates the expansion is seen in the bottom of the Charging Pump.

principal features still in use in such machines, viz.:—the evaporator, the compressor, the condenser, and the regulating valve between the condenser and the evaporator.

Although his machine was the forerunner of all the compression systems of the present day, Perkins does not seem to have had any more success in introducing it for practical use than Vallance had. Dr. Gorrie in 1845, seems to have taken the steps which led to the invention of the cold air machine with which the names

of Windhausen, Bell Coleman, Haslam, Lightfoot, Hall and others are associated, and which were the first that were successful in carrying meat from Australia to Europe. In 1850 Carre invented the ammonia absorption process. Between the years 1850 and 1860 Professor Twining in America, and Mr. James Harrison of Geelong, in Australia, devoted themselves to the improvement of Perkins' ether machine, probably without either inventor knowing what the other was doing, as there was not much communication between the two countries in those days. Twining is said to have had a machine at work between 1855 and 1857 in the State of Ohio, and Harrison, in the year 1855, was at work in Victoria and had made ice at Geelong. In the year 1859 the Harrison machines were introduced into New South Wales and manufactured by Messrs. P. N. Russell & Co., the author, at that time in the drawing office of the firm, was connected with this work from its initiation.

The original drawing of these machines is shewn on the wall, from which Fig. 2 is a reduction, as will be seen they were made with slide valves to the ether pump. One of them was at work at the rear of the Royal Hotel, George Street, Sydney, and supplied ice to a regular list of customers in the following year. In the same year (1860) Messrs. P. N. Russell made more Harrison machines to a horizontal design worked out by the author, who was then their chief draughtsman. These worked for many years in New South Wales and Victoria.[1] Messrs. Siebe, of London, had introduced the Harrison machine into England about the same time, and it is generally admitted in both America and England, that the very first ice machine ever adopted successfully for manufacturing purposes was one of Harrison's Australian ether machines made by Siebe, and applied to the extraction of paraffin from shale oil in 1861. Dr. Kirk invented a sort of regenerative air machine in 1862, which was also used for the cooling of

[1] Two original drawings of these machines made by the author and dated were exhibited, the larger one was printed in the *Engineer*, London, the same year.

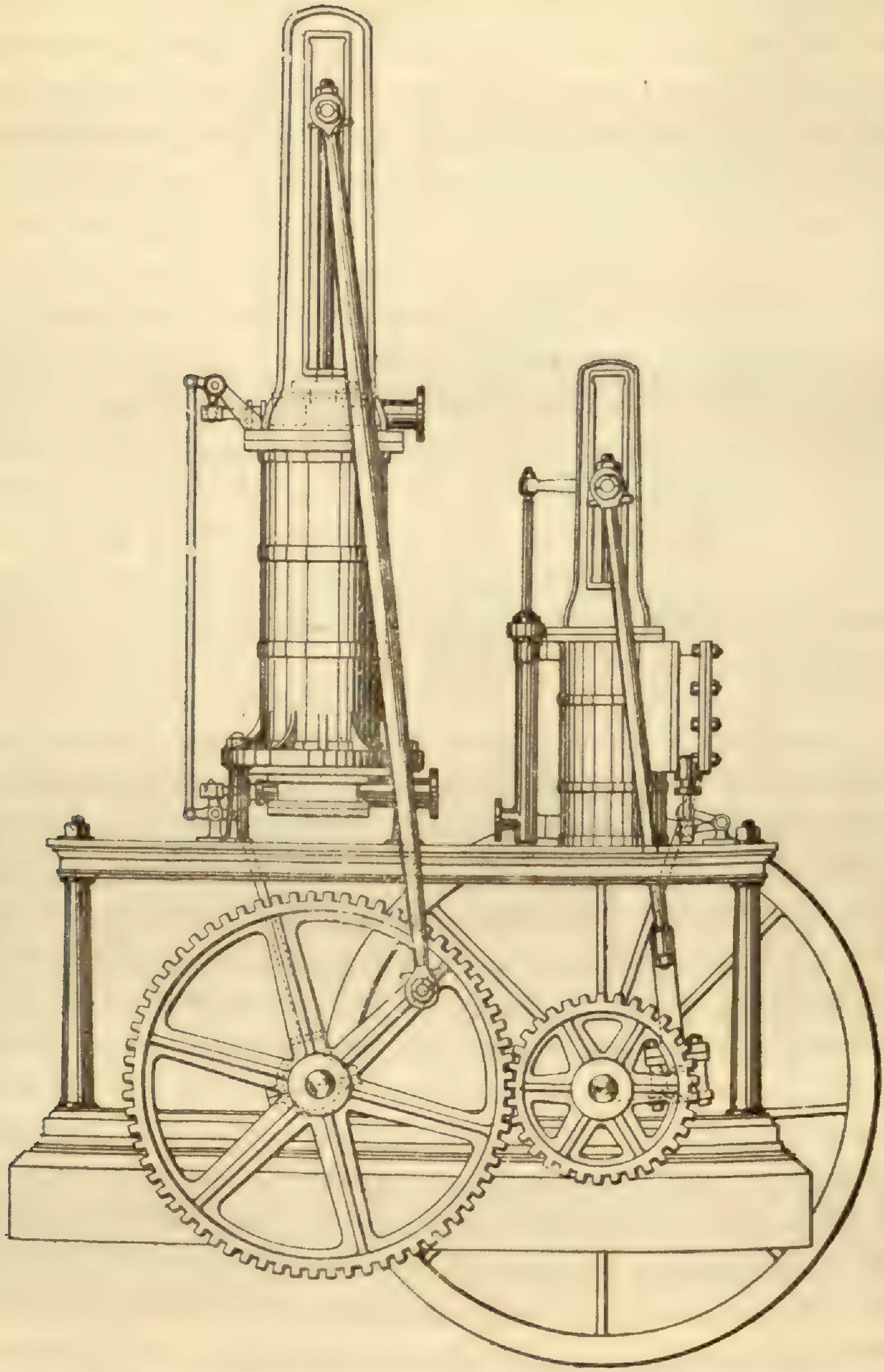

Fig. 2.

paraffin oil in Scotland. From the years 1861 to 1870 Mr. E. D. Nicolle, of Sydney, worked at the development of the ammonia absorption system first introduced into France by Carre, the latter

years in conjunction with the late Mr. T. S. Mort, and his machines at Paddington quite supplanted the Harrison ether machine in George Street. Many thousands of pounds were spent by Mr. Mort in experiments, not only with the ordinary absorption system, practical improvements in which were patented, but on a compressed air system, L. R. No. 181 of 1868; an absorption system assisted by a pump, L.R. No. 216 of 1869; and on a system for using nitrate of ammonia; all under the direction of Mr. Nicolle. The first compression machine designed in New South Wales for the use of anhydrous ammonia was patented by the author (No. 887 of 1880) and called The Colonial Freezing Machine, it embodied many devices which are now in general use. In 1885 the late Mr. W. G. Lock, engineer to the Fresh Food and Ice Co. of Sydney, patented a compound compressor for ammonia (L.R. No. 1729) consisting of two single-acting high and low pressure pumps side by side, very similar to the high class machines now being made by the "York" Manufacturing Co. of York, Pa. U.S.A. In 1881 the author designed the compressed air machine illustrated by Fig. 3, which had compound expansion and was specially intended for use by untrained men in the country where water for condensation was very scarce. This machine has worked successfully ever since, and will still deliver air at 50° below zero.

Great numbers of patents have since been issued in New South Wales to local engineers for compressers of more or less originality, and for other details of refrigerating machinery, and it must not be forgotten that Mr. J. D. Postle, by his New South Wales patent No. 180 of 1868, was one of the first persons in the world to understand and patent the use of an expansion cylinder in a cold air machine by which some of the heat held by the air is converted into work and a low temperature produced. It will thus be seen that New South Wales has, in the past, done a large share of the work by which the refrigerating machinery of the world has been brought to its present perfection. It is probable that, in the United States, the development of the ice machine

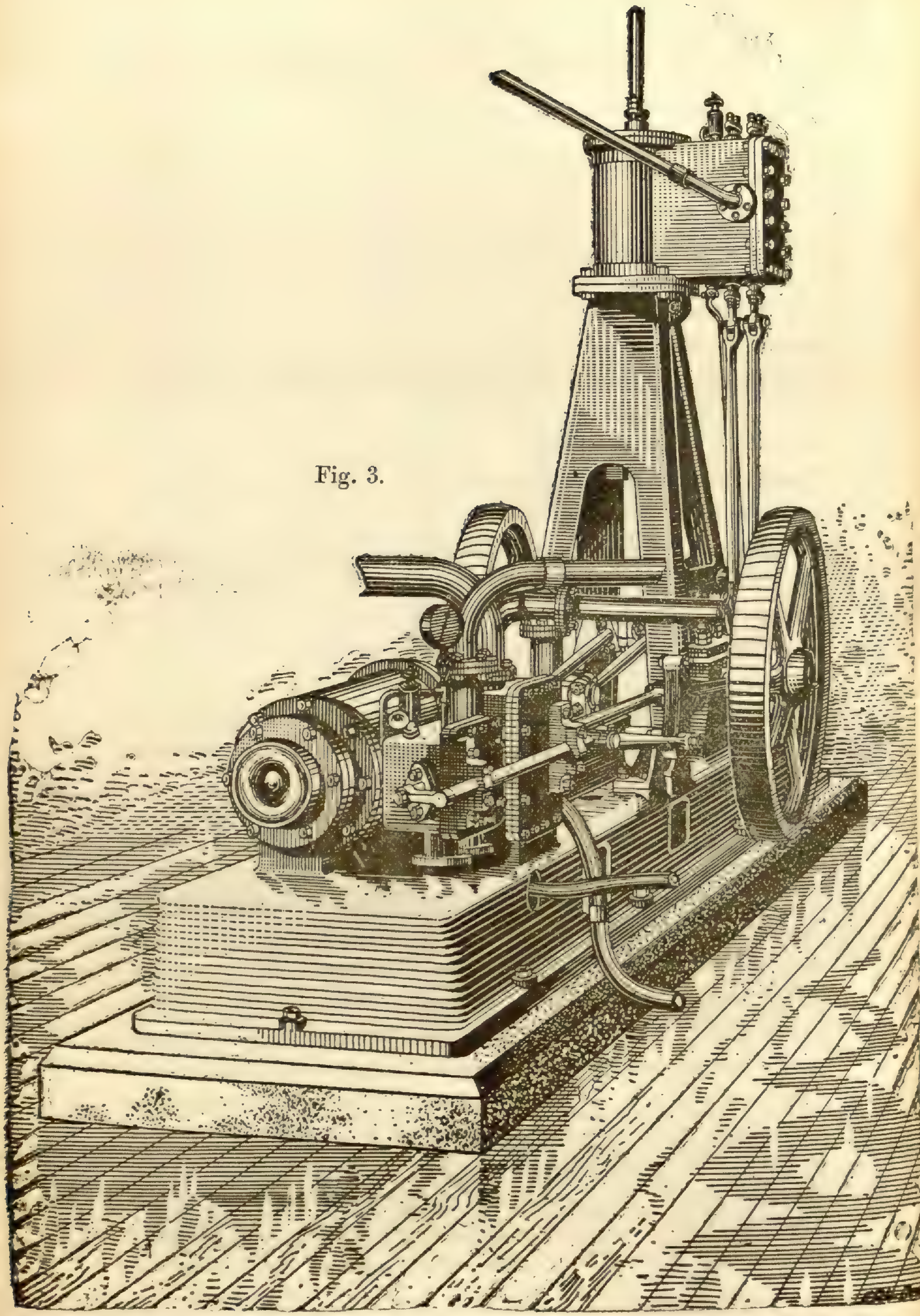

Fig. 3.

has been due more to its use in the brewery and the national taste for iced water than to other applications, and that in New South Wales the idea of freezing food products for export—first suggested in 1860 by the late Mr. Augustus Morris, when he offered to contribute £1000 towards the experiment of sending frozen meat to England—was the main factor which induced the late Mr. T. S Mort to devote his energies and probably a quarter of a million sterling towards the economic production of artificial cold. For more particulars as to Mr. Mort's great work the author would refer those interested, to an article in "Ice and Refrigeration."[1]

HOW CAN A MACHINE PRODUCE COLD.

Seeing that all machines work with more or less friction, and that the power thus lost reappears in another form of energy as heat—which is sensible and apparent—there is some excuse for the difficulty felt by the ordinary lay mind in comprehending the production of cold by machinery. It may be said at once that no combination of mechanism—with unlimited power to drive it—could alone make ice from water, and that an ice machine is simply an instrument for dealing with a medium in such a way, that it, the medium, is enabled to take up heat from the body to be cooled, and transfer it to another body. Except under very special circumstances which will be referred to later on, this heat is transferred to the water which is used for the purpose of condensation and goes to waste.

TWO CLASSES OF MEDIUM USED.

There are two distinct systems of mechanical refrigeration in use, operating by means of a medium. Under the more simple system this medium is a permanent gas which is alternately compressed and expanded, and is not liquefied under compression. In actual practice atmospheric air is alone used for this purpose and the machines are termed compressed air machines. Under a more complex system of mechanical refrigeration a volatile medium is employed, and in the operation of the machinery there

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[1] An (American Journal) August 1895.

is alternate liquefaction and volatilization. Although many different media have been tried, each of which has some special quality to recommend it, the principal ones to which reference will be made, are sulphuric ether, sulphurous acid, ammonia, and carbonic acid. In the system introduced by Carre a solution of ammonia in water is employed, the gas is driven off by the direct application of heat, and is again reabsorbed by the water after fulfilling its functions in the circuit of the apparatus; this is known as an "absorption system." The greater number of refrigerating engineers now adopt the compression system, but some well known authorities still advocate the advantages of the absorption system.

COLD AIR MACHINES.

These machines, coming under the first or simpler system already referred to, operate by virtue of the law that all mechanical work has a thermal equivalent. The diagram Fig. 4, illustrates the action of such a machine in dealing with a pound weight of air. At atmospheric density or 14·7 lbs. and a temperature of 62° one

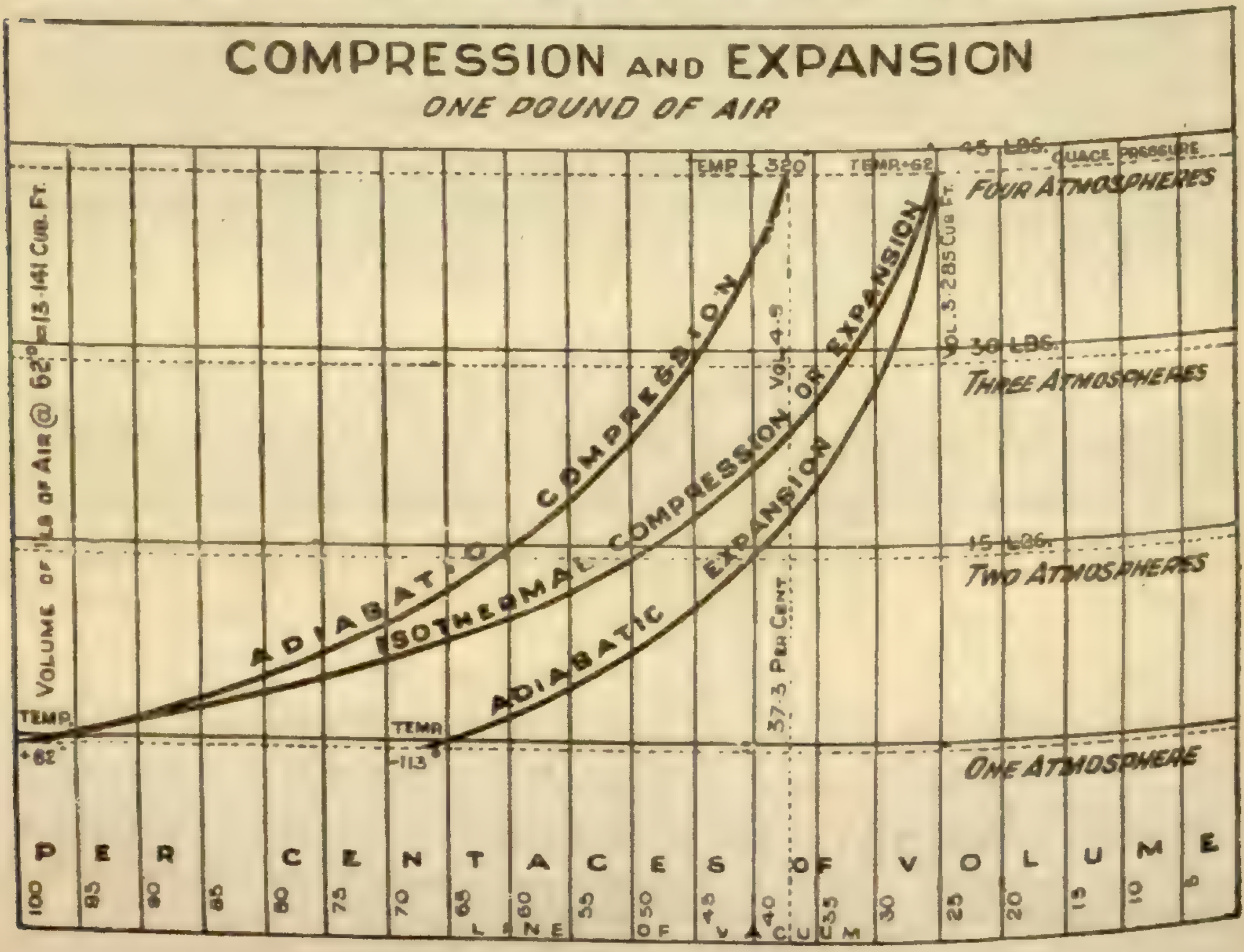


Fig. 4.

pound of air possesses the intrinsic energy due to its specific heat multiplied by its absolute temperature, *i.e.*, 62 + 460 = 523 degrees and it occupies a volume of 13·141 cubic feet, which is represented by the horizontal length of the diagram. If such a volume of air is compressed to a density of four atmospheres, then between 47 and 48,000 foot-pounds of energy will be required, and assuming a frictionless piston and a non-conducting cylinder, the air instead of following Mariotte's law, and by an isothermal compression occupying one-fourth or twenty-five per cent. of its original volume at the original temperature will rise to a temperature of 320° and fill 37·3% of the original volume, the difference representing the work performed by the engine in the work of compression. Now while it is under this increased tension, which with cold-air machines seldom exceeds five atmospheres, the compressed air may be passed through a condenser and have its temperature again brought to 62°, in which case the heat or energy of the engine will be communicated to the condensing water and for all practical purposes be lost. The air then only possesses the same intrinsic energy which it did before compression, but it is in a physical or mechanical condition which enables it to perform work by expanding again to atmospheric pressure. This expansion in practice is carried out in an engine similar to a steam engine which assists the working of the whole refrigerating machine, and the final temperature of the air is found by simple proportion thus—

as { compressed abs. temperature before condensation } is to { compressed abs. temperature after condensation

or 461 + 320 = 781 : 461 + 62 = 523

so is { original temperature before compression } to { final temperature after expansion

:: 461 + 62 = 523 : 348 absolute = − 113

or to make a simple proportion sum of it—

as 781 : 523 :: 523 : 348

and 348° − 461 = − 113°

In actual practice this theoretical low temperature is never reached, about—80° being the minimum and—50° an ordinary tem-

perature, the losses from friction and conduction being proportionately much less on large machines, as would be supposed; the results with these machines are also much affected by the moisture in the air and other causes.

Both in theory and in practice compressed air machines require very much more power (from four to six times) than other machines for a given abstraction of heat, they are therefore rapidly going out of use except for special purposes. It is possible in compressing air to reach very high and low relative temperatures without much difficulty, and it occurred to the author some sixteen years ago, that some of the heat or energy which is dissipated to the condensing water in these machines, and which is equivalent to the whole amount of the engine power, might be utilised by combining a compressed air refrigerator with a modification of the Du Tremblay ether engine, and he took out a patent in April 1880 (No. 812) for a refrigerating machine which had an ether engine as well as a steam engine to supply the power. In this machine the heat was to be abstracted from the compressed air by ether sprays on the condenser tubes, and the vapour thus produced was to be utilised to assist the steam engine and reduce the power. Although this machine has never been made, and in actual practice a very large percentage of the power thus saved would be required to overcome the extra friction resulting from the additional number of parts, still it appears absolutely certain that it is only in this direction by utilising the heat which is now thrown away in the condensers of refrigerating machines that any great improvement in the future of artificial refrigeration is possible.

In referring to the second or more complex system of mechanical refrigeration it was stated that a volatile medium such as ether, sulphurous acid, ammonia, and carbonic acid, was employed instead of a permanent gas as in the air machines; before considering the machines therefore, it will be well to consider some of the

PROPERTIES OF GASES.

The liquefaction of gases by pressure and cold has a special

attraction for scientists and is still being eagerly pursued, new triumphs in the way of simple apparatus for liquefying oxygen and atmospheric air being continually announced. Whenever a gas is vaporised from its liquid condition heat is taken up from some source of supply, and this is the property that is utilised in ordinary refrigerating machinery; but whereas water at atmospheric pressure boils at 212° very much lower temperatures are sufficient for the evaporation of the four gases used for refrigeration at atmospheric tension, viz:—

Sulphuric Ether,	Sulphur Dioxide,	Ammonia,	Carbonic Acid.
+ 96°	+ 14°	− 37°	− 124°

Now just as with water and steam, the boiling point of these and other gases means the temperature at which such gases liquefy as well as that at which their liquids pass to the gaseous condition; in fact a temperature under which the material may be either liquid or gaseous, depending for its condition upon the heat units contained in or held by it; such temperature depends upon the pressure to which they are subjected at the time, and conversely the pressure under which any gas can be liquefied depends upon its temperature. For the practical purposes of artificial refrigeration the lowest temperature to which heated gases under pressure can be reduced is limited by the temperature of the water used for condensation;[1] this water may be as low as 45° or 50° in temperate countries, and in hot climates may exceed 90°.

The diagram Fig. 5 shews in graphic form the vapour tensions of carbonic acid, ammonia, sulphurous acid, ether, and water under the temperatures met with in practical work, or their boiling points under widely varying conditions as to pressure. For instance it will be seen that carbonic acid, which under atmospheric pressure will boil at 124° below zero, requires about 1080 lbs. per square inch to liquefy it at 96°, affording a great contrast to water, the boiling point of which at 14·7 lbs. or one atmosphere is

[1] For experimental purposes to produce very low temperatures the condensed gas may be cooled by a second refrigeration and a step by step process adopted for attaining the lowest extreme possible.

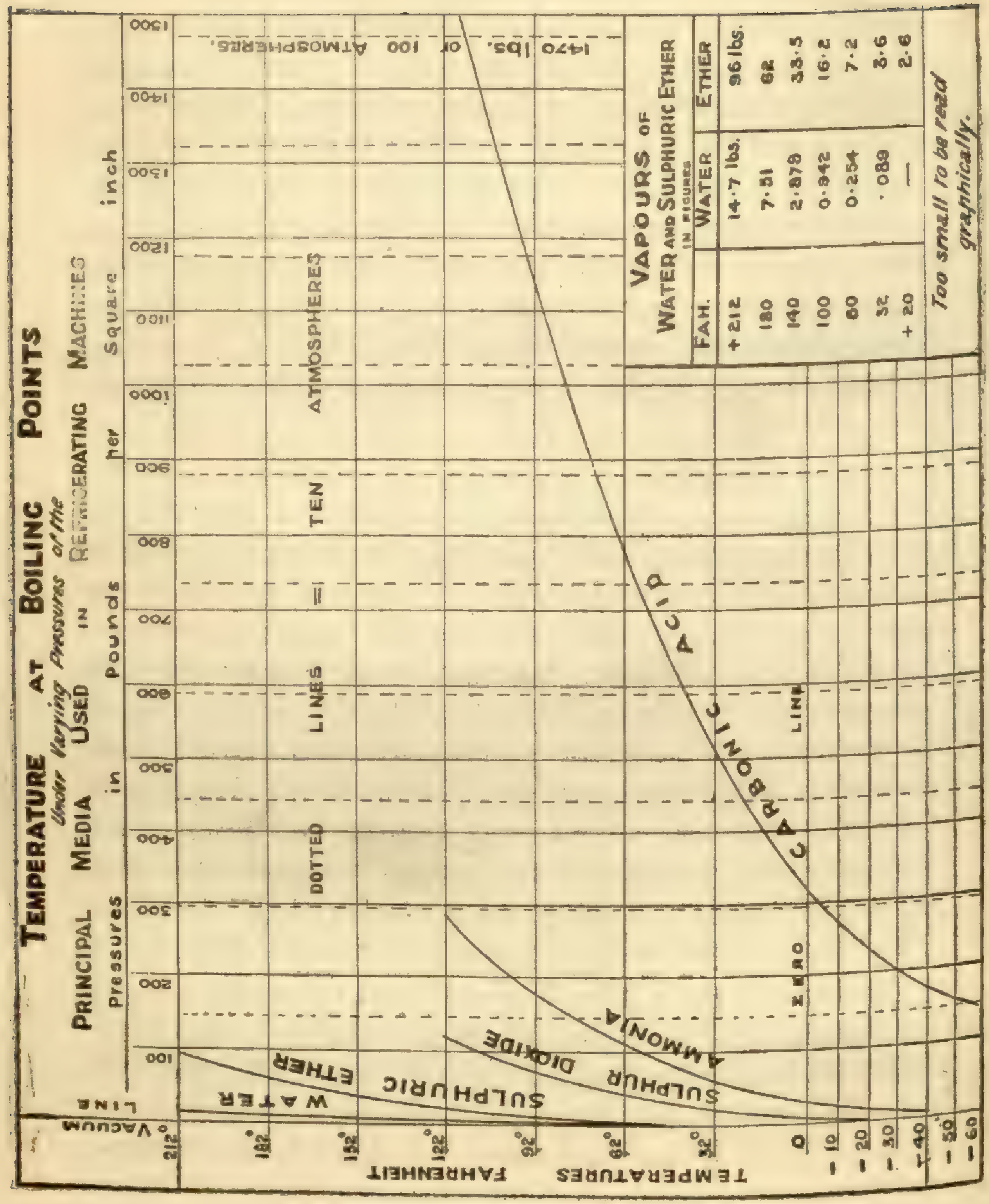


Fig. 5.

212° and which requires the pressure reduced down to 0·089 of 1lb. per square inch—a very high vacuum—to enable it to vaporise at 32°. Again sulphuric ether which boils at 96° under atmospheric pressure must be attenuated to at least 12 lbs. below atmos-

pheric pressure before it will evaporate at the freezing point of water. From these figures it will be noted that machines for making ice by the evaporation of water or ether must work with a vacuum, their pumps exhausting their refrigerators to pressures below that of the atmosphere.

THE LATENT HEAT OF LIQUEFACTION IN ITS APPLICATION TO REFRIGERATION.

Although the low temperature at which a volatile medium may be made to boil in the coils of a refrigerator has a very important bearing on the production of cold, as in so doing it abstracts the heat necessary for its vaporization, there is another property of the medium that has been before referred to, which has a great deal to do with the results, and that is the latent heat of liquefaction, or the number of heat units that a pound of the medium will take up in passing from the liquid to the gaseous condition. To make the importance of this property clearer, suppose

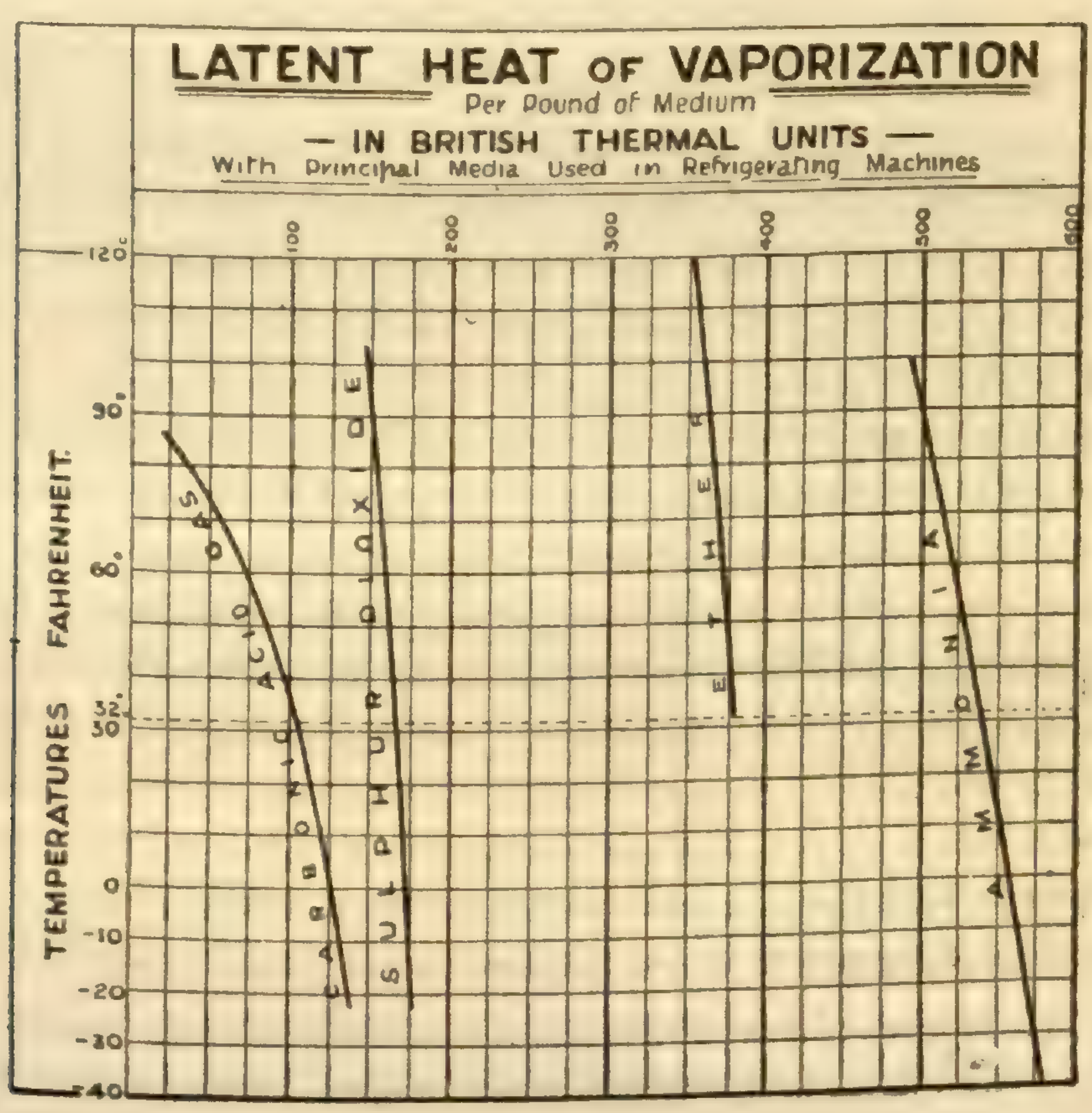


Fig. 6.

that a pound of one medium in evaporating will abstract heat enough to bring two pounds of the substance to be refrigerated down 100°, while one pound of another medium will under similar conditions lower the temperature of ten pounds of the same substance but only 50°, then the medium in the later case would, other things being equal, be two and a half times as efficient for refrigerating as the first one, because it would abstract two and a half times as many thermal units in its conversion into vapour. If the substance to be cooled is water, then two pounds lowered 100° represents 200 B.T.U., while ten pounds lowered 50° would be 500 B.T.U. In order therefore to find the relative efficiency of one pound of a given refrigerating medium for abstracting heat in the refrigerator, the latent heat of liquefaction must first be taken into account. Diagram Fig. 6 shows by curves the latent heat of the four principal media before referred to through considerable ranges of temperature.

USELESS WORK PERFORMED IN THE REFRIGERATOR.

When a gas is liquefied under the influence of pressure—whether produced by a pump, or through the direct application of heat—and the abstraction of heat by cooling it in a condenser, the resulting liquid is necessarily at a temperature something above that of the condensing water and is ready to change its condition again when those influences are removed. In actual practice the pressure is retained in the condenser or liquid receiver by an expansion or flash valve, which regulates the passage of the liquid refrigerant into the coils of the refrigerator, releasing its pressure at the same time to that of the refrigerator; under these conditions the liquid immediately boils or evaporates, and in so doing abstracts heat from the metal of the coils and the air or liquid surrounding such coils; but it must be particularly noted that it has to be cooled itself before it can cool the refrigerator down to any given or required temperature and that therefore a certain amount of its actual cooling power is not effective for external refrigeration.

The amount of heat or the number of thermal units that is thus lost before any useful refrigeration is done, is the product of the

specific heat of the medium multiplied by the number of degrees it is lowered in temperature. All this cooling power is absolutely lost because the medium has to be heated up again by the expenditure of energy at every circuit it makes through the machine.

THREE PROPERTIES OF A GAS CONCERNED IN FORMING AN EFFICIENT REFRIGERATING MEDIUM.

From the foregoing remarks it will be understood that the efficiency of different gases for refrigerating purposes is mainly dependent upon three properties possessed by them, and not upon any one special quality, and these are—

1. A low temperatue of vaporization upon which depends the degree of cold that can be produced by such evaporation.

2. A high latent heat upon which depends the total number of heat units which will be abstracted by the evaporation of a given weight of the medium.

3. A low specific heat upon which depends the percentage of the heat taken up by (2) or the amount of cold produced which can be utilised.

WHY AMMONIA IS SO LARGELY USED IN REFRIGERATING MACHINES.

Although ether, chloride of methyl and several other media have been used in refrigerating machines besides those already referred to, and some are still advocated under special conditions, yet ammonia is now used more than all the rest put together, experience having proved the many advantages it possesses. The principal reason why ammonia has supplanted the use of other liquids as the circulating medium in refrigerating machinery is because it has such a high latent heat of vaporization, being 555 B.T.U. at zero, against 123 for carbonic acid, and 171 for sulphurous acid, that is to say one pound of ammonia at zero Fahrenheit in passing from the liquid to the gaseous condition would take up 555 thermal units, while the other liquids would take up less than a third and less than a fourth respectively. There are some compensating advantages in the case of carbonic acid on account of its high specific gravity which makes its heat of vaporization for

a given volume very much greater than ammonia, their relative volumes at zero for equal weights being about 1 : 32·4, and thus the relative dimensions of the compressors for equal refrigerating effects are as $\frac{123{\cdot}2 \times 32{\cdot}4}{555} = 7{\cdot}2$ nearly for ammonia, to 1 for carbonic acid. This would be an advantage, other things being equal, but carbonic acid reaches a critical condition (at 88 Fahr.) where its efficiency rapidly falls off when the condensing water is warm, and many carbonic acid machines have their refrigerator and condenser one inside the other. By this device power is expended to cool the condensing water and make the machine work, this being totally unnecessary with ammonia, as machines using it often work with the condensing water at 90° or over without any great falling off in efficiency. In a paper read before the Ipswich (England) meeting of the British Association, on "Carbonic Anhydride Machines,"[1] by Mr. Hesketh, one of the Directors of Messrs. Hall of Dartford, a firm that has introduced these machines all over the world, it is clearly shown that, with a machine producing 9,360 lbs. of ice per twenty-four hours, the horse power with different temperatures of cooling water varied as under :—

Inlet cooling water in degrees Fahr.	Ice in 24 hours.	I.H.P. of Engine.
52	9360 lbs.	15·62
75	,,	20·03
85	,,	27·26
90	,,	28·20
100	,,	42·10

making it obvious that, in a carbonic anhydride machine, with an increase of temperature from 50° to 90° in the condensing water, the power required is double, and with water at 100° it is nearly threefold.

The relative efficiency of a cubic foot of ammonia gas under different temperatures from 65° to 105° would vary as under ; the

[1] *Engineering*, Nov. 1st, 1895.

figures regresenting the refrigerating effect in thermal units as given by Siebel :—

Gauge suction pressures in lbs....		4	9	16	24	33	45
Corresp. temp. in refrigerator..		– 20	– 10	0	10	20	30
Temp. Fahr.	Gauge condenser pressure in lbs.	Refrigerating effect of a cubic foot of ammonia gas in British Thermal Units.					
65	103	33·74	42·28	54·88	68·66	85·15	106·21
75	127	33·04	41·41	53·76	67·27	83·44	104·09
85	153	32·34	40·54	52·64	65·88	81·73	101·97
95	184	31·64	39·67	51·52	64·49	80·02	99·85
100	218	30·94	38·80	50·40	63·10	78·31	97·73

Shewing that with back pressures from 4 to 45 lbs. the increase of condenser temperature from 65° to 105° only reduces the efficiency of a cubic foot of gas about nine per cent.

THE ABSORPTION SYSTEM.

Although compression machines now largely outnumber those working on the absorption principle, and are daily replacing them, it must be remembered that the latter led the way and for a long time carried all before them. Introduced in 1858 by Ferdinand Carre of France, and in 1861 into Australia by E. D. Nicolle, this system was largely developed by the munificence of the late T. S. Mort, and supplanted the ether machines of Harrison. In an absorption system an aqueous solution of ammonia is the medium used, instead of pure anhydrous ammonia. Taking a solution of twenty-five parts of ammonia in seventy-five parts of water in a boiler or still, the application of heat will cause both gas and aqueous vapour (steam) to be given off in the proportion of, say, 90% of ammonia gas to 10% of steam or vapour. This combined vapour is passed into a condenser under the pressure maintained in the boiler or still, which is dependent on the temperature and volume of the condensing water. By the combination of this pressure with the transfer of heat to the condensing water the ammonia is liquefied. The liquid ammonia is allowed to expand in the coils of the refrigerator where it either freezes or cools the substance it is employed to refrigerate. The gas being driven out of the boiler or still by the pressure generated, the solution left, called the weak liquor, is then drawn out and cooled

in another condenser, after which the ammonia from the refrigerator and the mother liquors are allowed to re-unite in a vessel termed the absorber, from which the system takes its name; after this it can be returned to the boiler to go through the same cycle of operations over and over again. It will thus be seen that this is a very simple process, for, besides the several vessels, coils and valves, there is no machinery proper required beyond the pump to return the liquor from the absorber to the boiler, and even that can be dispensed with by ingenious arrangements like the "Montejus" whereby the strong liquor is lifted by pressure to a receiver and descends to the still by gravity. This class of machinery being cheap and the process simple, absorption machines are still made and used under certain conditions, and many elaborations have been made to secure fractional distillation and dessication of the gas, and also by means of exchangers to utilise some of the waste heat, but it is perhaps more on account of the greater amount of condensing water required, than the greater power wasted in the absorption machine, that the compression system has replaced it.

Water, at atmospheric pressure and 60° Fahr., will absorb about seven hundred times its volume of ammonical gas, and therefore the watery vapour that distills over with the gas largely discounts the efficiency of the machine, because it not only requires fuel to raise it, but a supply of cold water to condense it, and although increasing the amount of fuel required for a compression plant might not alone condemn the use of the absorption system where fuel is cheap, yet in most parts of Australia the requirement of double the quantity of condensing water would be a serious drawback, and has led to great numbers of them being replaced by compression machines.

MECHANICAL COMPRESSORS FOR AMMONIA.

As soon as the defects inseparable from the absorption system were understood, inventors reverted to the work of Jacob Perkins, Harrison and Twining, but it was a very different matter compressing a subtle gas like ammonia up to twelve or more

atmospheres than it was to deal with ether vapour at a very low tension, and the result has been a long series of inventions having for their object the improvement of the compressor. English, American, and Continental inventors have all contributed to the perfection which refrigerating compressors have now reached, most of them keeping one special point in view to the neglect of others not so important in their opinion, hence we have a large choice of ammonia compressors in the market of most admirable workmanship, each one of which is claimed by its respective agents to be the best in the world. It is hardly possible that they can all be the best seeing the wide divergence which exists in their design, proportions, and construction, but it will be instructive to examine into the details of the principal machines that are made and see how they set about the work they undertake to do.

It must be admitted that theory and natural laws have no favorites, and that the conditions which result from compression and expansion are the same for every one. But theory alone is of little avail in the work of the mechanical engineer, some of the biggest failures have resulted from hugging one main central theory so closely that all the little attendent theories were forgotten, and it is the knowledge of the little theories which constitute practical experience.

THE CHARACTERISTICS OF AN IDEAL REFRIGERATING MACHINE.

Refrigerating machines generally consist of a compressor in combination with a steam engine, but such compressor may have its piston driven by any other power without affecting its efficiency for the work of refrigeration. It is therefore desirable in an enquiry into the merits of any compressor to consider its various points under separate heads. First the work to be done in compressing a gas, for which the design and construction of the compressing cylinder with its piston and valves are the principal instruments concerned : and secondly the connection of the same to the motive power, assuming that any form of engine, slide valve, Corliss, simple, or compound, is open for use ; and that therefore the merits of the engine itself, apart from its attachment to the

compressing apparatus, need not take up our time; but it is important that the design of the whole machine should be such as to simplify its erection and secure economy of power in its subsequent working. Thirdly, there is the provision for easy examination of parts, maintenance in repair and working order, which should be full and ample.

Under the first head may be placed the following characteristics of a compressing cylinder which are directly concerned with the work done on the gas:—

1. On the in or suction stroke the cylinder should fill with gas at a pressure as little below that in the expansion coils as possible and the outlet valve should be "tight."

2. The piston and rod should work with the maximum of "tightness" in order to prevent leakage; and with the minimum of friction so as not to generate heat or require extra power to move them.

3. On the out stroke the inlet valve should not permit any leakage, and the whole contents of the cylinder, less the minimum of clearance, should be discharged through the outlet valve at a pressure as little above that in the condenser as possible.

Under the second head, dealing with the general design and construction of the whole compressor:—

4. The machine, other things being equal, should be self contained on one sole plate so as to be easily erected at the minimum of expense for foundations; because the cost of the foundations—and very costly ones are required by some compressors and their steam engines—must be taken into account before it is possible to make a proper comparison of the cost of different machines of the same power in working order.

5. If it is required to minimise the strain on the crank pins, shafts, and connecting rod, and keep down the weight, cost, friction, and wear of those parts; the work of the compressor, crank, rods, and crossheads should be double acting instead of single acting, and the ratio of compression should be as small as possible

during both strokes (distributing the work over as large a portion of the crank pin's path as possible); because with single and double acting cylinders of equal capacity and piston speed the single acting one must have double the piston area of the double acting one, and must therefore transmit double the stress to the connecting rod and cranks.

If high mechanical efficiency and low working expenses are aimed at then :—

6. In order to minimise the friction in the bearings and prevent the loss of power which results from indirect action, the connection of the engine piston to the compressor piston should be as direct as possible, and the crank shaft, with the crank pins and connecting rods, should also if possible, take up and transfer the *difference* between the powers exerted and required by the steam and compressor pistons respectively at any given position, instead of the *sum* of these powers, during each revolution of the fly-wheel.

Under a third head there are other points of importance connected with the maintenance of the whole machine in working order as :—

7. The pistons and valves should be easily accessible for examination and renewal. The cylinders should be simple castings.

8. All joints, and covers or bonnets should have plain faces, and such things as double or treble connections with bridges under one joint face should be avoided in order to make connections simple and certain. Lastly, all wearing surfaces should be adjustable and easily adjusted.

THE WORK TO BE DONE IN A COMPRESSING CYLINDER.

When a gas is compressed in a cylinder, the work performed by the piston is not uniform throughout its stroke for the reason that the pressure increases as the volume is reduced following a curve which is dependent upon the heat during compression. This curve is called "adiabatic" when no heat passes from the cylinder during the compression of the gas ; and "isothermal" if so much heat is transferred during the operation that the gas is maintained

at the same temperature throughout, as was shewn by the diagram when referring to compressed air machines. Some compressors have water jackets and others dispense with them. At present it is enough to remember that the piston of an ordinary compressor commences its stroke without offering any resistance to the engine apart from friction, because the gas is then of the same pressure on both sides of it; the resistance commences with the stroke however, and increases until the condenser pressure is reached, when the work of the piston continues uniform to the end of the stroke; the greater the ratio of compression the smaller the portion of the stroke during which gas passes the delivery valve, and the greater the importance of reducing the waste space or clearance in the cylinder ends.

ON THE WAY IN WHICH IDEAL CONDITIONS ARE MET IN TYPICAL EXAMPLES OF REFRIGERATING COMPRESSORS.

1. That the cylinder should fill with gas at a pressure as little below that in the expansion coils as possible. The diagrams on the wall shew twelve different compressors, single and double acting, vertical and horizontal. The horizontal machines with horizontal valves must have strong springs to close them and the pressure required to move the valve is thus a loss. The vertical double acting compressors with horizontal valves have the same drawback with the further disadvantage of a greater waste space or clearance. In the author's design, in "Hercules," and "Auldjo," all single acting and vertical, there is provision for absolute equilibrium above and below the piston, quite apart from the resistance to the inlet valves; and in the Antarctic Compound, this provision is found in the low pressure cylinder. It will be noticed in the author's two designs, that the working barrels are plain cylindrical castings and the equilibrium ports can be drilled, whereas in other machines there are complicated castings with cored passages and cored ports. The Frick machine has such a large valve in its piston so beautifully balanced on springs that it will easily open for the admission of gas. The oil in the De La Vergne compressor would seriously affect it in

filling with gas, did not this machine run at a very low speed. It may therefore be said that the Auldjo, Antarctic, Frick, and Hercules machines perfectly fulfil the first condition.

2. The piston rod should work gas tight with the minimum of friction. The use of oil as a seal to the piston rods of these machines has made a seal possible, but with horizontal double acting machines like the "Linde" this oil has to be pumped by special arrangements into a lantern bush. In all but the Antarctic Compound the oil being inside the cylinder is liable to be carried into the system, and by coating the interior of the pipe coils affect their conducting power. In the Antarctic Compound the rods are not ordinary piston rods at all, and the oil is not in the cylinder, hence the most perfect seal is obtained without these disadvantages.

3. The whole contents of the cylinder, less the minimum of clearance should be discharged at the minimum pressure. In the De La Vergne machines the oil ensures the full expulsion of the gas, and also in those machines which, like the "Frick," "Auldjo," and "Antarctic," have delivery valves the full area of the cylinder, the piston can sweep the full contents out. In certain types of machines, which, like the "Hercules," have two valves on the top cover, their area is limited and the effect cannot be the same. While therefore, some machines offer the best facilities for taking in the gas, and others have the best arrangements for expelling it, the "Antarctic" designs follow the better features of both classes.

THE DESIGN AND CONSTRUCTION OF THE WHOLE MACHINE.

The diagram from a steam engine cylinder, as we are all aware, is just the reverse of that from a compressor, the maximum pressure being exerted upon the piston at the beginning of the stroke and reducing rapidly by expansion after the steam is cut off, at the time when the resistance of the gas to the compressor piston is increasing.

Some of the illustrations on the walls represent straight line compressors, which are double acting with their steam engine

combined as one machine, and Fig. 7 is the diagram from the

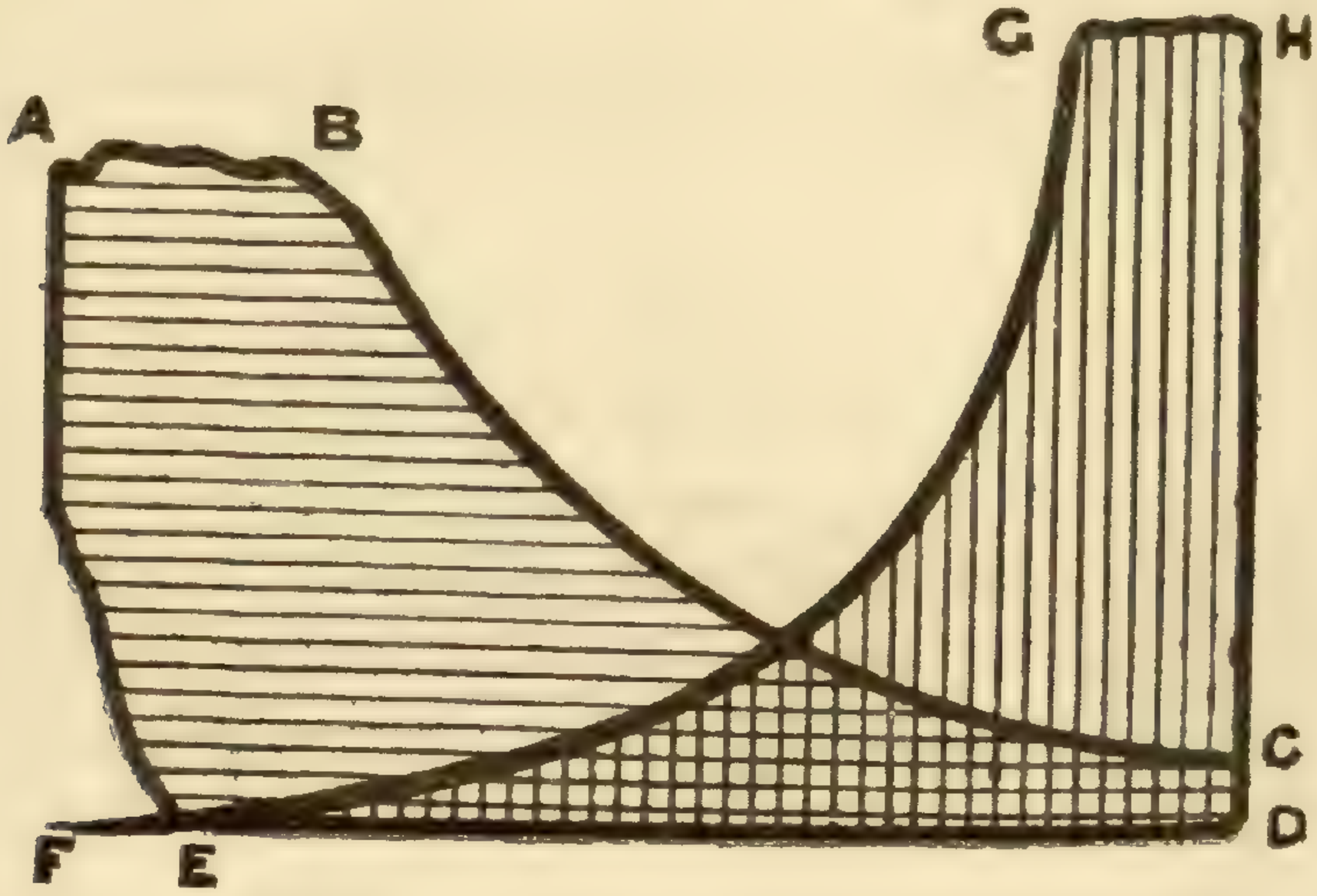


Fig. 7.

two cylinders of such machine. The portion hatched with horizontal lines represents the power or force applied by the steam cylinder, and the portion with the vertical lines the resistance of the compressor, the area covered by the intersected lines shews all the power which is applied directly to its work, that with plain horizontal lines shews the power which has to be imparted to the fly-wheel at the commencement of the stroke, and which is restored as per the area with plain vertical lines at the latter part of the same. This arrangement entails so much friction and expense for working parts and heavy fly-wheels that it has become customary to set the engine of a refrigerating machine at right angles to the compressor in order that the power exerted throughout the respective strokes may more nearly correspond with the resistance of the compressor.

One of these machines designed by the author sixteen years ago, (Fig. 3) is still at work on the South Coast with vertical engine and horizontal compresor, but some of the best machines in the world by the most eminent makers, such as the "Frick," "De La Vergne," &c., are arranged with horizontal engines and vertical compressors. In other machines, as the "Linde" and "Hercules," the engine and compressor are two entirely separate machines on separate

foundations, but have one shaft in common with their respective cranks at opposite ends set at the angle desired. The former (Frick &c.) is the better mechanical arrangement as it is possible under it to make the whole machine complete in itself on one foundation. The only way to secure the simplicity which should characterise an ideal compressor is to adhere to the straight line connection, so that instead of the crank shaft having to take the sum of the work represented by the engine and compressor diagrams it should only have the difference to deal with. To make this clearer, suppose at a particular part of the stroke of a right angled machine the force exerted by the engine piston is 1000 lbs. and the compressor requires 900 lbs. to move it, then the whole stress of 1,900 lbs. is communicated to the bushes of the connecting rods and main journals; on the other hand, in a straight line machine, doing the same work, the 900 lbs. would be applied directly from one piston to the other, and only 100 lbs. would be communicated to the connecting rods and journal instead of 1900 lbs.

When the author realised, from a consideration of these facts, the great opening that there was for improvements in this direction, he set to work to see how they could be brought about, but it soon became evident that it was only by making the diagrams from the engine and compressor more nearly coincide, that an ideal straight line connection could be effected; as a result of two years' work the machine known as the Antarctic Compressor has been devised, which is shewn in section by the diagrams and will now be described.

There is nothing new in compound compression. Mr. Lock's patent of 1885 has been already referred to, and the author designed a large compound air compressor in 1884, which is still in the Colony, but most compound compressors have a complicated arrangement of valves and passages from one cylinder to the other, and separate stuffing boxes for the piston rods of the high and low pressure cylinders.

Now the peculiarities of the Antarctic Compound Compressor shewn by Figs. 8 and 9, are:—

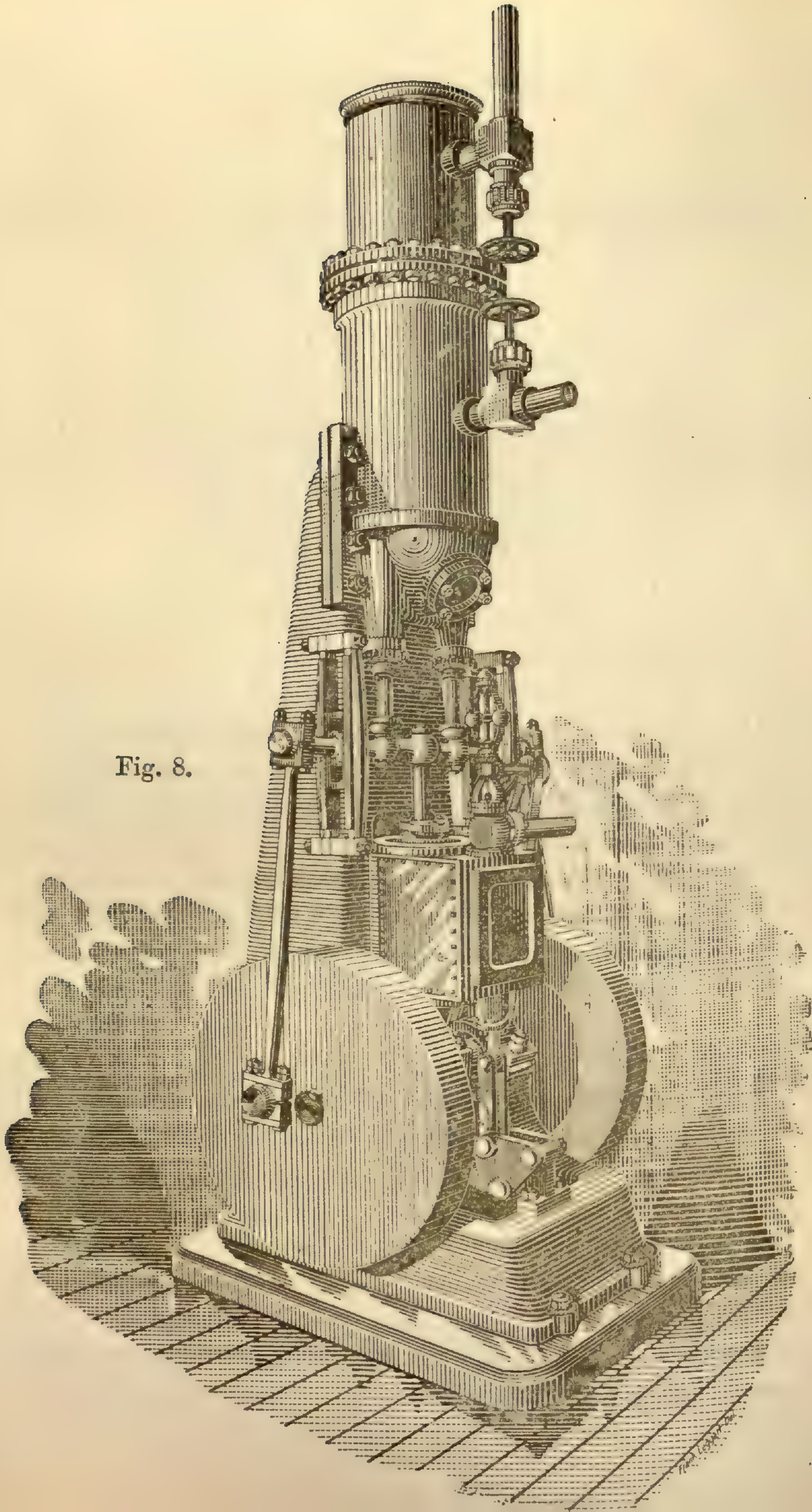
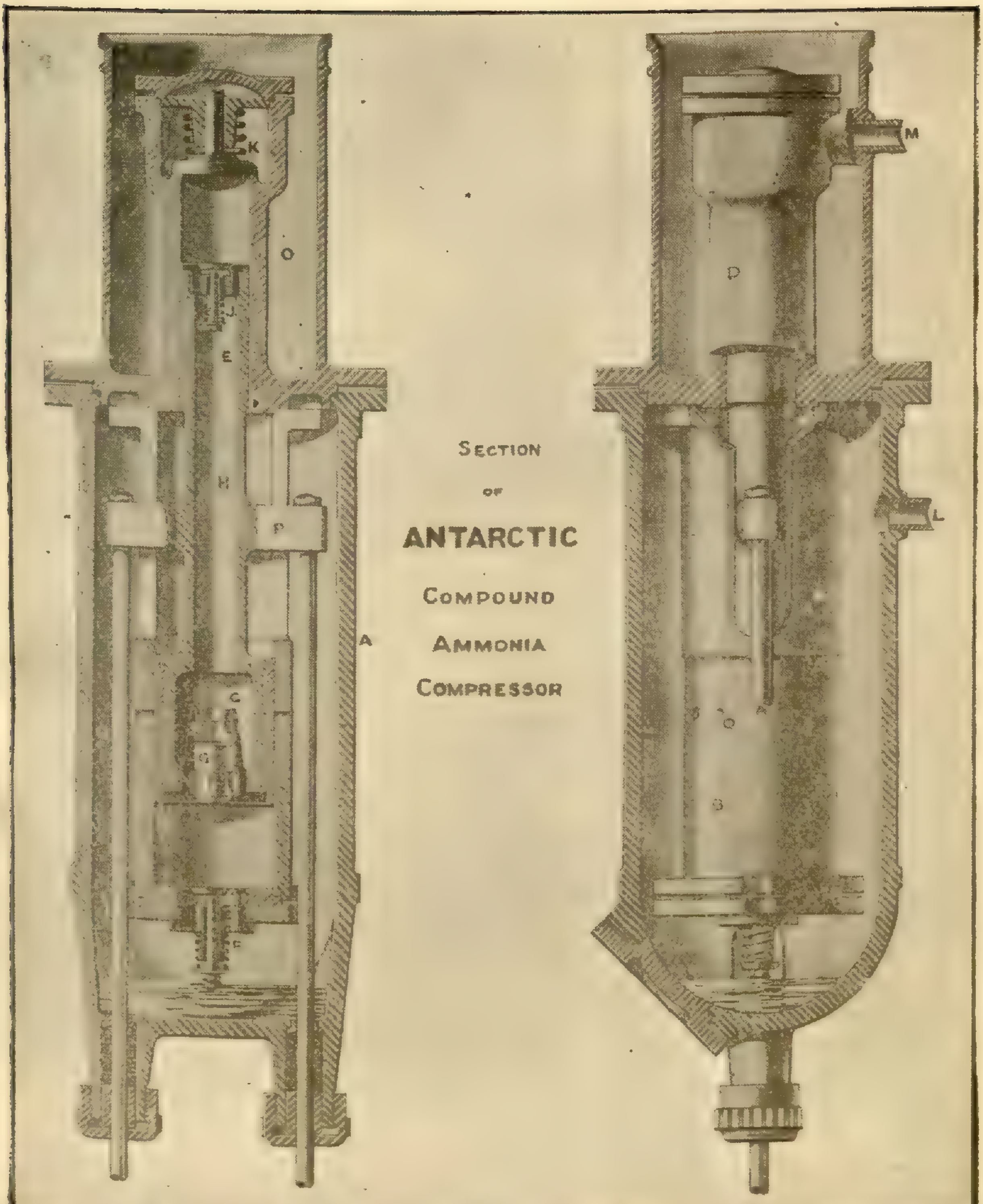


Fig. 8.



SECTION

OF

ANTARCTIC

COMPOUND

AMMONIA

COMPRESSOR

Fig. 9.

A—Main Casing
B—Low Pressure Cylinder
C—Low Pressure Piston
D—High Pressure Cylinder
E—High Pressure Piston
F—Low Pressure Inlet Valve
G—Low Pressure Outlet Valve
H—Passage from Low to High Pressure Cylinder
J—High Pressure Inlet Valve
K—High Pressure Outlet Valve
L—Main Inlet Branch
M—Main Delivery Branch
N N—Piston Rods
O—Water Jacket to H.P. Cylinder
P—Cross Head to Piston Trunk
Q—Equilibrium openings to ensure filling of L.P. cylinder at full pressure

1. There are no piston rods proper as the cylinders are open mouthed and face one another.

2. The two pistons are so connected that a passage through the centre of them permits the flow of gas directly from the low to the high pressure cylinder, without going outside and through connecting pipes.

3. The two cylinders are enclosed in a casing, so that any possible leakage past the piston is intercepted and again drawn in at the suction valve, and they are made simple castings without belts or passages to affect the homogeneous character of the metal.

4. The enclosing casing can be filled up with several inches of oil in the bottom without any being put in the cylinders proper, and the seal thus made renders leakage of gas through the stuffing boxes impossible.

5. The valves can be made as large as desired for the area required, and can be all inspected and taken out by opening only two doors.

6. Owing to the work being divided between the up and down strokes, and the proportion of the pistons being as 3 : 1, the effective pressure reached in the first stage or down stroke is only about one-half of the ultimate pressure, and as the pressure on one-third of the area of the large piston is neutralised by the pressure on the small piston during the down stroke, the effective stress or load is only about one-third of what it would be in an ordinary single acting compressor. During the up stroke it is manifest that with only one-third the area, a given ultimate pressure of gas can offer only one-third the resistance which an ordinary compressor piston would exert on the working parts of the machine.

7. The resistance at any time to the pistons of a given sized compressor under this system are from one-third to two-fifths of that exerted in an ordinary compressor, but the work is distributed practically throughout the whole of the two strokes, instead of being confined to the latter portion of one stroke only.

The four diagrams, shewn by Fig. 10, illustrate graphically the comparative strains on the crossheads of an ordinary and an Antarctic Compressor respectively throughout one revolution of their

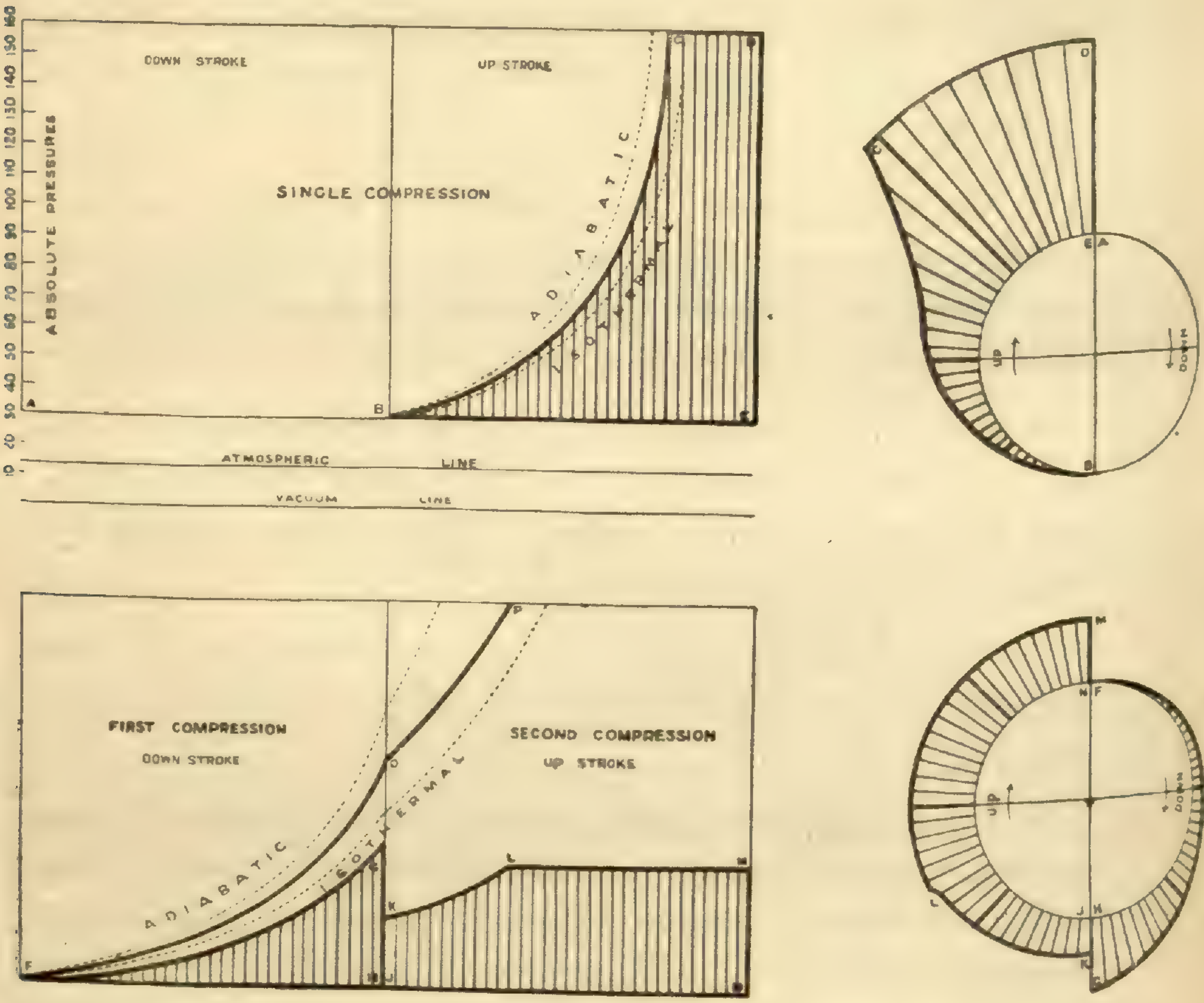


Fig. 10.

shafts. A to B representing the down stroke and B to E the up stroke, working from 30 lbs. to 160 lbs. per square inch pressures (absolute). The length of the vertical lines shows the resistance offered to the piston in pounds per square inch, and pounds absolute if the area of the piston is taken as unity; which work in the left hand figures is all concentrated at the latter part of the up strokes. The dotted lines represent the adiabatic and isothermal curves respectively, the actual curve of compression being assumed as half way between them. In the lower left hand figure the pressures during the down and up strokes of an Antarctic Compound

Compressor are represented as when doing exactly the same work and under similar conditions as in the ordinary one, the curves of pressure rising to exactly the same height as in the upper figure, but the vertical lines representing resistances offered to the pistons are only about one-third the height of those in the single compressor. This results from the effective areas of the large piston (for the down strokes) being only two-thirds, and that of the small one (for the up strokes) only one-third of the area respectively of the ordinary compressor piston. These resistances are it is seen, distributed through the whole of both strokes, instead of being concentrated at the upper end of one only. The two right hand figures show these diagrams placed around a circle, the left hand half of which, or semi-circle, represents an up stroke, and the right hand one a down stroke respectively, the letters of reference serving as a guide. The distribution of the work performed by the compressor pistons during one revolution of the crank shaft is thus graphically displayed by the length of the radial lines. The upper of the two showing that a relatively large expenditure of power is required during about only one-sixth part of a revolution in an ordinary machine, while the Antarctic Compressor requires a comparative even expenditure of power (amounting to only about one-third of the former) but distributed throughout the whole of the circle of the crank pins travel.

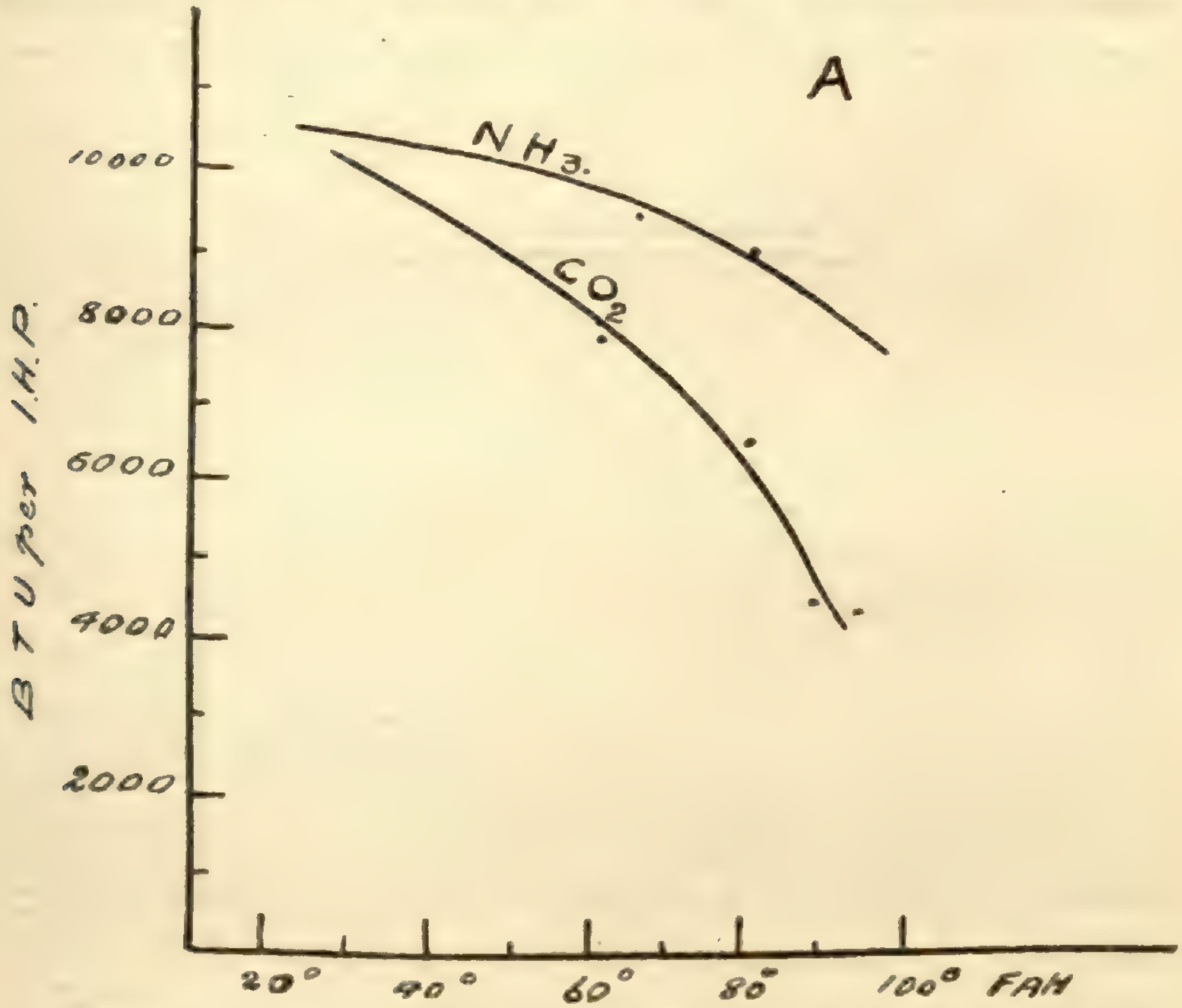
Discussion.

Mr. Cruickshank said it was a matter for congratulation that the present development of refrigeration was largely due to Australian energy and enterprise, and Mr. Selfe had done his fair share of the work. What the author had attempted to do was very important, and although it might not be altogether original he had done it in a very practical way. He could not do better perhaps than compare the working of refrigerating machinery with what takes place in a steam engine. Of course the action of a refrigerating compressor was simply that of an engine reversed. The strains in a steam engine are very great, and we endeavour

to lessen those strains by putting the steam through two or three cylinders as the case may be. The author had adopted a direct system of connection in his refrigerating machine, thus allowing of the reduction of the strain to a minimum, reducing friction in a very material degree, and enabling the various parts to be made lighter ; another very important item is that the machine is so nearly balanced. As a distinct and very important branch of engineering, refrigerating machinery cannot be overlooked ; inasmuch as some of our principal industries depend to a very large extent upon the efficiency and economy of the machines which are used in the refrigerating process. The many cases of failure of refrigerating machinery resulting in the loss of cargoes of meat were known to all, and a potent cause of failue no doubt lay in the fact that the machinery was often not properly duplicated.

Mr. W. B. STATHAM said he made in 1893 eleven tests on two different machines, each of twelve tons ice making capacity per twenty-four hours. One a Linde machine using ammonia, and the other a carbonic acid machine. These machines were working under exactly the same conditions, and all measurements were carefully gauged, and the results checked by an independent engineer. The object of these tests was to find out in the first place the relative efficiency of the two refrigerating mediums before mentioned when working with different temperatures of cooling water. The initial and final brine temperatures were kept constant as near as possible throughout the eleven tests, and as the duty of the machine fell off consequent on the rise in temperature of the cooling water, so the quantity of brine in circulation was proportionately reduced. No measurements were taken until all fluctuations in temperature had ceased. The diagram marked " A " shewed two curves, the lower one representing the results obtained with the carbonic acid machine, and the upper one the results obtained with the ammonia machine. Plotted as ordinates are the number of B.T.U. extracted by each machine per indicated horse power, and as abscissæ are given the temperatures of the refrigerant (ammonia or carbonic acid) measured

before admission to the refrigerator. The two curves shew that at a normal temperature (60° F.) the ammonia machine is 20% more efficient than the carbonic acid machine, and even with cooling water below freezing point, 5% more efficient, (in this case



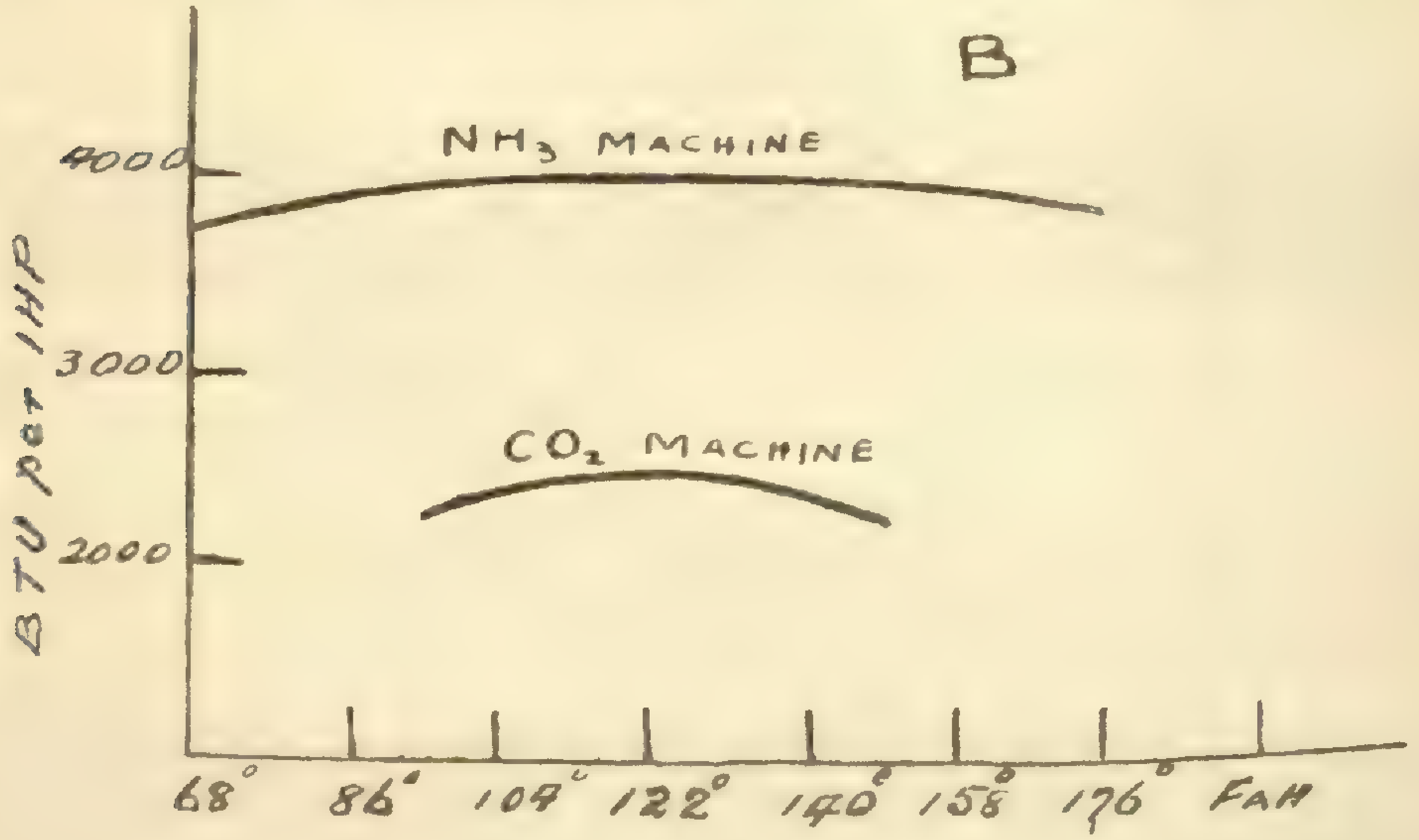
Temperature of refrigerant measured before the regulating valve.

the cooling water consisted of brine. With cooling water above 87° F. (that is above what is always considered to be the critical point of carbonic acid) the ammonia machine required just half the power required by the carbonic acid machine for doing the same amount of refrigerating work under exactly the same conditions. The above results are practically confirmed by the figures given in the paper read by Mr. Hesketh.[1]

He, Mr. Statham, carried out several experiments to show how the efficiencies of the two machines compared when working with a low and a high temperature of pressure pipe, that is allowing

[1] See page xlviii. *ante* and *Engineering* November 1, 1895.

the gases to leave the compressor in a super-saturated or superheated condition. In these tests the conditions were identical. The two curves on diagram "B" shew that the temperature of the pressure pipe of the ammonia machine may be varied through a range of about 100° F. without causing a very great falling off in efficiency, whereas the temperature of the pressure pipe in the



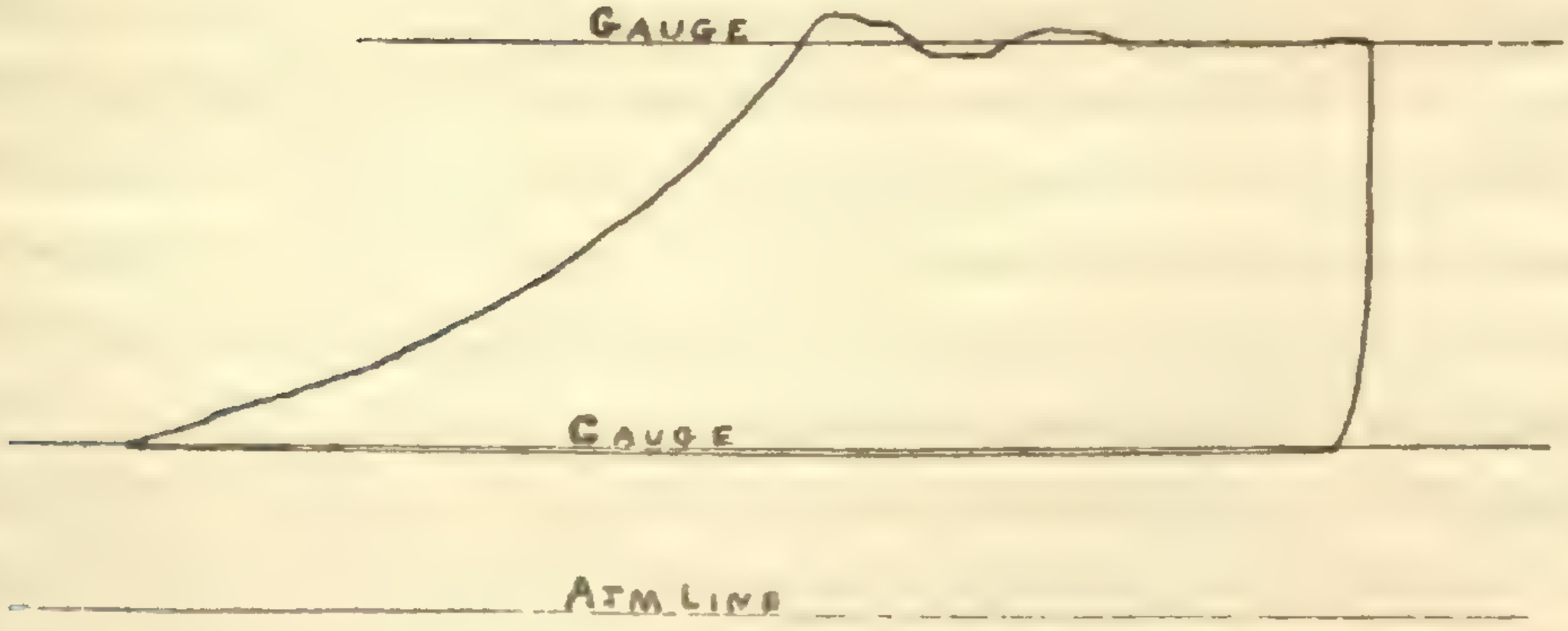
Pressure Pipe Temperatures.

carbonic acid machine can only be varied through a range of about 50° F. for the same falling off. The maximum efficiency was obtained when the pressure pipe temperature was about 122° F. If the temperature were raised to 176° F. the efficiency of the machine at once fell off. The vapours aspirated by a Linde compressor contain sufficient liquid ammonia (very finely divided) to absorb by its evaporation the heat produced during compression, the vapours leaving the compressor in a saturated condition.

The author has stated what in his opinion should constitute an ideal machine. With regard to No. 1, diagram "C" was taken from a twelve ton Linde compressor, it will be seen that on the suction stroke the pressure very nearly corresponds to the pressure shown on the refrigerator gauge, (see line marked 'gauge.') and on the compression stroke with the pressure shown on the condenser gauge, both the suction and delivery valves

Scale 5·6 m m = 1 Kg
1″ = 64 lbs.

C



give the maximum of tightness as the point on the diagram showing the end of the suction stroke is very sharp, the same being the case at the end of the compression stroke. The suction and delivery valve springs do not offer much resistance to the opening of the valve, where the valves are anything like tight a greater resistance to the opening of the valve would be exercised by the film of oil which would be between the valve's surface and its seat.

With regard to No. 2, the results of some experiments made on two twenty-four ton Linde Compressors to ascertain the power required to overcome the friction in the stuffing box, shewed that with a condenser pressure of 180 lbs. per square inch, the power required was somewhat less than one quarter indicated horse power the gland remaining perfectly tight and cool. It is not absolutely necessary to have a special pump for pumping the oil through the lantern bush, as the oil is not under pressure. A sight drop lubricator is frequently used. As regards oil getting into the system of a plant, this is practically prevented by the insertion of an oil collector ; a little oil in the compressor is an advantage as it ensures the tightness of the valves and piston rings.

Dealing with No. 4, the general design and construction of the machine, Mr. Statham said that this point has received the Linde British Refrigeration Co's. special attention, and as a result of

several years experience with the self contained simple and duplex machines, they have now produced a triple expansion horizontal surface condensing steam engine combined with three separate compound ammonia compressors arranged all on the same bed plate; the three steam cylinders are placed parallel to each other and are connected up to a three throw crank shaft; the ammonia cylinders are placed tandem to the steam cylinders, and are driven by prolongations of the piston rods; most of the parts are interchangeable, and the steam engine can be worked either single, compound, or triple expanion, condensing or non-condensing as the case may be. The crank shaft is also in three separate parts connected by two couplings.

Mr. Statham was surprised at Mr. Cruickshank's remark regarding the insufficiency of duplication in marine plants, as it has been the practice of many makers for years past to supply duplex machines on board ship. Marine plants should have always a duplex machine and duplicate coolers, plants of this type have been taking home valuable cargoes of meat through the tropics using only one half of the machine, the other half being kept as a stand by, and generally only used when the ship is loading up, and it is necessary to cool the holds down rapidly.

Mr. HOUGHTON said the author's statement as to the part played by Australia in the early history and development of the freezing machine was most valuable, as it placed on record the names of the men to whom credit was due. In the discussion on the first paper read on refrigerating machines before the Institution of Civil Engineers,[1] a long list of the works bearing on the subject which had appeared up to 1874 was given, and it shewed how many men had been at work trying to perfect the machine at that early date. The very low temperatures attained in the expansion cylinders of machines using air for refrigeration affected the strength of the steel piston rods and they broke, although the stress was very much within the ordinary elastic limit of the

[1] Proceedings Inst. C.E., Vol. XXXVII., p. 271.

metal, the fracture being very crystalline. Triple expansion engines driving compressor direct have been made previously to that mentioned by Mr. Statham. Single acting compressors are often preferred, both on account of the stuffing box being subject to the suction pressure only, and also to the easier adjustment of the clearances.

The machine which the author considered embodied most of the points of the ideal machine as formulated in the paper, certainly did offer a very direct course for the gases, and being compound gave a much more equable resistance throughout the revolution of the crank than non-compound compressors possibly could. He had seen one of the authors machines at work and it certainly ran very steadily, it was not bolted down in any way but simply resting on blocks of wood.

Mr. STOKES said that in his historical remarks the author had omitted to mention the Sulphuric Acid Atmospheric Machine, which although successful was not an unqualified success, because the sulphuric acid absorbed so much water it had to be renewed frequently, and was consequently intermittent. He (Mr. Stokes) thought that an ideal machine should consist of few parts all of ample size; he would consider the single acting compressor with duplex cylinders preferable, the vertical type of compressors with horizontal engine required the most attention and more floor space would be necessary, but the increased efficiency would compensate for that. In certain types of machines, which like the "Hercules" have two valves on the top cover, the valves do not require to be very large to take up the compressed gas. He objected to compound machines—if, when something happened to one side of it the whole machine was laid up; with the duplex machine if one part breaks and an overhaul is necessary, the other portion can be kept working while repairs are effected.

Professor WARREN said, we may illustrate the changes which a substance undergoes in a direct heat engine or a reversed engine by means of pressure—volume or entropy—temperature diagrams. Mr. Selfe had made use of the well known pressure volume dia-

grams, and it is proposed to show how the same problem may be represented by means of entropy-temperature diagrams. When a substance takes in or rejects heat, it is said to change its entropy. The change of entropy being expressed thus

$$\Sigma \frac{\delta Q}{\tau}$$

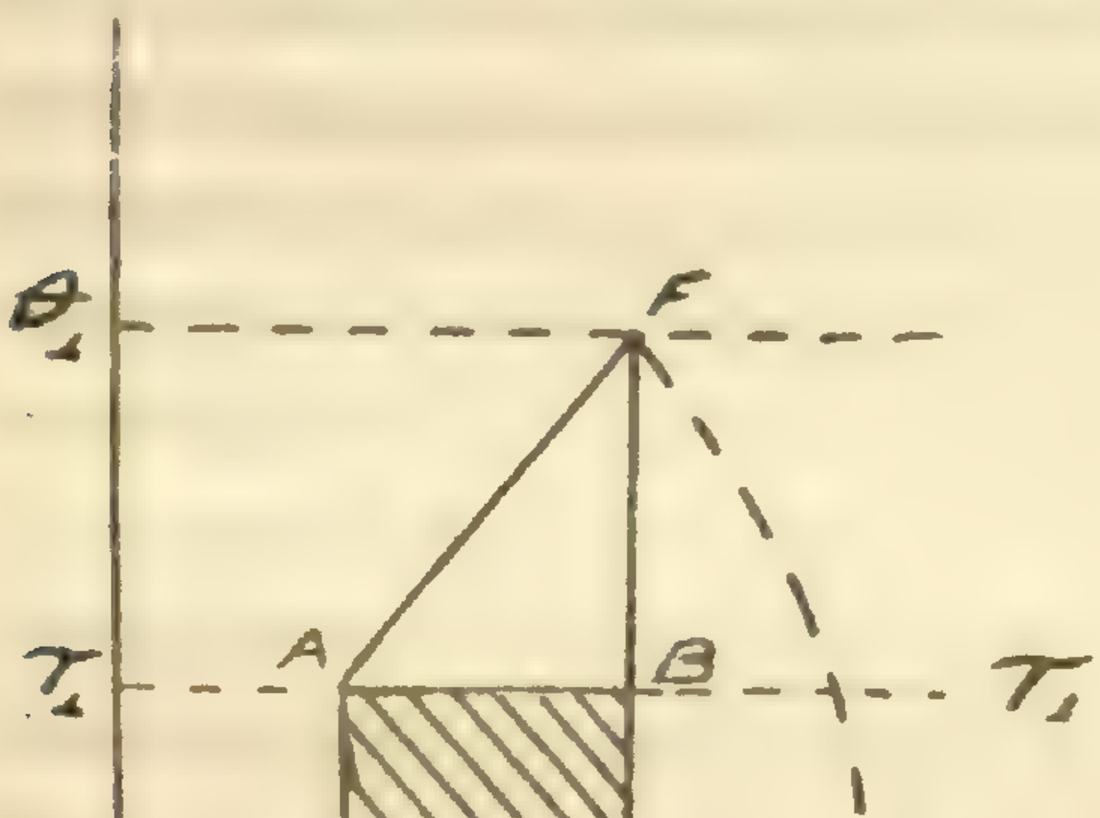
δQ represents the heat taken in or rejected, and τ the absolute temperature which the substance had at the time. When an entropy temperature curve is drawn for a complete cycle of changes it forms a closed figure, since the substance returns to its initial state. To find the area of the figure we must integrate through the complete cycle thus—Let Q_1 and Q_2 represent, the heat received and rejected respectively, and $A\,W$ the work done in thermal units, then—

$$\int \tau dQ = Q_1 - Q_2 = WA,\ A = \tfrac{1}{778}.$$

For Carnot's cycle—

$$\frac{Q_1}{Q_2} = \frac{\tau_1}{\tau_2} \therefore \frac{Q_1 - Q_2}{Q_1} = \frac{\tau_1 - \tau_2}{\tau_1} \therefore A\,W = \frac{Q_1}{\tau_1}(\tau_1 - \tau_2)$$

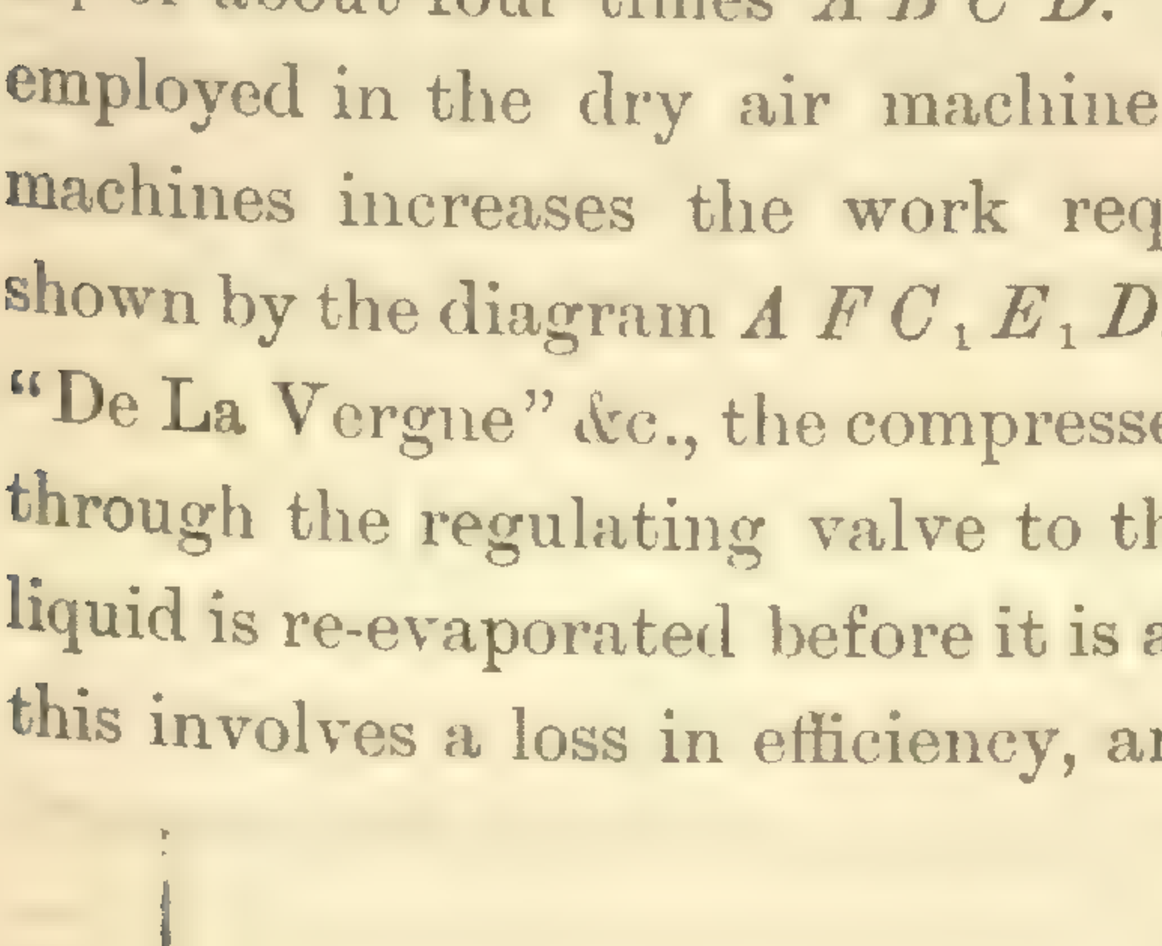
and the diagram is represented by a rectangle $A\ B\ C\ D$.



We can show by means of this diagram why a dry air machine is necessarily less economical than a machine which depends on the principle of evaporation and compression of a vapour such as ammonia, carbon dioxide, sulphur dioxide etc., but in the first place the cycle for a dry air machine will be compared with Carnot's cycle. In the dry air machine the heat is not all abstracted at τ_1, but the reduction of temperature in the cold chamber is effected by intro-

ducing the air at a much lower temperature θ_2, and this is heated up to the temperature τ_2, increasing the work done by the area $E\ D\ C$ where θ_2 is the absolute temperature of the cold air introduced from the expansion cylinder to the cold chamber. The process is thermodynamically wasteful to the extent shown by the area of the triangle $E\ D\ C$, where $E\ D$ is usually about twice $A\ D$. Again the compressor aspirates air at a temperature τ_2 and compresses it with a rise of temperature θ_1. If this occurs adiabatically the rise is $\theta_1 - \tau_1$ which is equal to $\tau_2 - \theta_2$, hence the heat is rejected between the temperatures τ_1 and θ_1 and the increase in work done is shown by the triangle $A\ F\ B$ which is equal to the triangle $D\ C\ E$. Hence the whole area representing the work done in a dry air machine assuming adiabatic expansion and compression is $F\ A\ E\ C$, or about three times the area $A\ B\ C\ D$.

But actually the result is worse than represented by this area as there is an interchange of heat through the cylinder walls and the work done is somewhat as shown by the dotted area $A\ F\ C_1\ E_1$ or about four times $A\ B\ C\ D$. The relatively large cylinders employed in the dry air machine as compared with the vapour machines increases the work required to be done beyond that shown by the diagram $A\ F\ C_1\ E_1\ D$. In the "Linde," "Hercules," "De La Vergne" &c., the compressed liquid flows from the cylinder through the regulating valve to the cooler., and a portion of this liquid is re-evaporated before it is admitted to the expansion coils, this involves a loss in efficiency, and it is the object in all refrigerating plant to minimise this loss. It may be represented by an addition to the Carnot cycle $A\ B\ C\ D$ of $A\ E\ D$, where $A\ E\ D$ represents the increase in the work done in consequence of the heat units abstracted at decreasing temperature.



In a perfect process the nature of the working substance is immaterial, but in the actual process the efficiency depends other things being equal, upon the ratio of the specific heat to the latent heat of the volatile liquids such as ammonia and carbonic acid. The critical temperature of carbon dioxide is 88° F. when its latent heat is zero, hence these machines lose efficiency when the condensing water is about this temperature which must necessarily be the case in warm countries. In America they are using dry air machines on board ships in the Navy in which the air is initially compressed by means of a special pump—the Allen Dense Air Ice Machine—so that the weight of the substance circulated is much greater and the machinery less bulky. The air is under a pressure of 60 lbs. per square inch, and is compressed up to about 210 lbs. per square inch.

Mr. SELFE said that in the historical portion of the paper he had no intention to attempt to write a complete history of artificial refrigeration, or to record all the steps by which it had arrived at its present position. It was only because there are works dealing with the matter which entirely ignore the part which Australia has played in this connection, that the historical references were introduced at all, and he wished to place these Australian facts on record, before they could be contradicted or give rise to controversy.

Mr. Statham gave some very interesting particulars regarding the falling off of efficiency in carbonic acid machines corroborating the statement made in the paper on that matter. The statement as to the valves on the Linde machine not affecting the pressures was not accompanied by diagrams, and it was not stated that they can do without springs at all or with as light springs as vertical valves all opening upwards—as in the Antarctic machines. With regard to oil in the cylinder, all good machines are now fitted with oil collectors as well as the "Linde." The advantages of wet compression as advocated by Mr. Statham, can, if valid, be availed of in the first stage of the Antarctic machine as well as in the Linde system.

Mr. Houghton's experience with the repeated fracture of the piston rod of a cold air expansion cylinder is not unique, because the Glebe Island machine had similar trouble. But the cold air machine designed by the author and shewn by illustration has worked for over twelve years now without once having a similar mishap.

Mr. Stokes corroborated the necessity which exists in ordinary cases for setting the engine crank at right angles to that of the compressor, and drew some diagrams which were practically identical with those shewn by the author to illustrate the amount of power required to be stored in the fly wheel of a compressor under ordinary conditions. He, Mr. Stokes, summed up the qualities of his ideal compressor thus:—Few parts of ample size with two vertical single acting compressors and the engine between them, vertical for small sizes and horizontal for large machines. He must have lost sight however of the fact that in comparing such an arrangement with that of the Antarctic machine he had to provide three sets of guides, connecting rods and cranks, and three separate lines of force instead of one; that the sum of all the strains instead of the differences has to be borne by the bearings, that expensive crank forgings were necessary to make a good job, and that the power lost by friction would probably be about three times as much as in the direct acting machine.

In the past large profits were attached to the working of refrigerating machinery and economy of power was not a matter of great importance, but with the competition and continual striving for improvement daily taking place, any arrangement which reduced the frictional losses as well as the wear and tear by more than one half was a much more serious matter, and led the author to work out the arrangements shewn in Figs. 8 and 9.

WATER CONSERVATION SURVEYS OF N. S. WALES.

By H. G. McKINNEY, M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, August 19, 1896.*]

WHILST the first great rush for settlement on the lands of this Colony was in progress, the question of the conservation of water was left entirely to the individual occupiers of the land, and no idea of the necessity for dealing with it from a national point of view seems to have occured to those who had charge of the framing and administration of the laws. It was not surprising that settlers of British origin should have treated the subject in this manner. Nevertheless it was a great mistake to overlook the fact that the conditions here are entirely different to those existing in the British Islands, and that precedents for the best course of action should be looked for in countries whose conditions more nearly resemble those of this Colony.

As settlement progressed, every dry year brought an increasing number of proposals regarding works for water conservation which it was suggested should be taken in hand by the Government. With very few exceptions the schemes thus brought to the notice of the public and of the Government, were of a visionary and impracticable character. In some cases a fair knowledge of the physical geography of the Colony was alone sufficient to show that the proposed schemes were not feasible; but it soon became obvious that in order to place the Government in a position to know both what could, and what could not be done, a comprehensive system of levels and surveys was necessary, as was also a system of recording the heights and gauging the discharge of the rivers. This was the position of affairs when the present writer took up the duties of Engineer to the Royal Commission on the Conservation of Water in 1884. Previous to that time, records

of the heights of several of our rivers had been maintained by the Government Astronomer, and some had also been kept by the Department of Harbours and Rivers; but the information thus recorded was intended chiefly for use in connection with navigation. In many cases no records were entered when the rivers were low, and in some cases the gauges were so fixed that their zero was above the water level when there was a discharge of many hundreds of cubic feet per second. While the records kept under such circumstances were undoubtedly of great value for purposes of navigation, the fact that they took little or no account of low discharges, rendered them of comparatively little use so far as questions relating to water conservation were concerned. There were thus two great questions to be taken up and dealt with—the first, to ascertain what quantity of water was available for distribution and utilization, and the second, to determine the directions and extent to which this water could be distributed. While it is the main object of this paper to deal with the latter question, it may be stated in regard to the former, that gauges have been established at all the important points on the western rivers, that these gauges have in nearly all cases been connected with the general levels of the Colony, and that an extensive series of discharge observations has been taken.

It required little investigation to show that the Central and Western Divisions of the Colony are the great field for water conservation and irrigation, and that the great alluvial plains west of the Dividing Range present both the greatest requirements for water and the greatest facilities for its distribution. The natural and systematic course of action was, therefore, to determine by levels and surveys the rates of fall in the land extending from the places where the plains commence, to ascertain the conditions of the rivers and creeks under their varying circumstances, and to examine the lakes and other natural depressions of importance which serve, or could be made to serve, as storage reservoirs.

In designing the system on which this work was to be conducted, the great principle aimed at was to obtain the maximum amount

of information with the minimum amount of work and expense. To attain this object, the lines to be levelled and surveyed were sketched on the county and sometimes on the parish maps, but the surveyors employed were not only permitted, but requested to deviate from these lines under certain circumstances which were indicated in the instructions. In addition to the instructions regarding deviations from the main lines laid down on the maps when the natural features proved different to what was anticipated, the surveyors were required to run cross sections or other extra lines to determine the position and extent of any natural features which would have an important bearing on any works for the distribution of water. Cross sections of creeks and rivers were taken at places where the lines of levels touched their banks, and in taking levels of running water both the date and hour of observation were in every case noted. The main lines of levels constituted a series of connected geometrical figures, so that there were numerous closes and easy means of checking. The work was done by contract, and it is very satisfactory to be able to state that, as a general rule, it was highly creditable to the surveyors employed. Occasionally it appeared desirable to send an officer of the regular staff to check portions of the work, and this was easily done by running lines across two or more circuits. In addition to the checks thus made, surveyors were required to connect their levels with those of railway lines and railway trial surveys whenever the lines came near work done by the Railway Department. This gave many independent checks, and a further important check was afforded by the levels taken many years ago along the River Murray by the Department of Harbours and Rivers.

The datum adopted for the water conservation levels throughout the Colony is that of the Railway Department, namely, Sydney high water mark.

The examination of the level books and the apportionment of the differences occurring at the end of long closes, was a matter requiring much care and labour. The degree of accuracy specified

was that the errors in large circuits should not exceed a foot in a hundred miles, and this limit was not allowed to be departed from except in a few cases where creeks or ridges were numerous, or where there were other conditions unfavourable to great accuracy.

In addition to the checks already described, it occurred to the author that it would be interesting to combine the outlines of a series of circuits and thus to obtain one great circuit for an entire district or a river basin. The results for a number of such circuits were prepared by Mr. D. R. Alderton, Licensed Surveyor, of the office staff, and from these the following may be cited :—

(1) Commencing at Albury and carrying levels through Jerilderie, Conargo, Wanganilla, Moulamein, Euston, and Gol Gol to Wentworth, the levels taken by the Water Conservation Branch close with those taken by the Harbours and Rivers Department along the River Murray with a difference of only 1·56 feet. The circuit includes eight hundred and fifty miles of levelling by the Department of Harbours and Rivers, and four hundred and fifty miles by the Water Conservation Branch.

(2) Commencing at Wagga Wagga and levelling along the north side of the Murrumbidgee to close at Hay, the distance by the water conservation survey being two hundred and three miles, and that by railway one hundred and eighty-nine miles, or a total of three hundred and ninety-two miles, the difference at the close was 0·54.

(3) Commencing at Hay and following lines through Oxley, Balranald, Euston, and Gol Gol to Wentworth, the difference at the close was only 0·50. The circuit here included eight hundred and fifty miles by the Harbours and Rivers Department, two hundred and sixty-four miles by railway, and two hundred and eighty miles by the water conservation surveys, or a total of 1,394 miles.

(4) Commencing at Hay and following lines through Oxley, along the north side of the River Lachlan through Booligal, Hillston, Euabalong, Condobolin, and Forbes to Cowra, the closing

difference with the railway levels was 2·34 feet, the distance being two hundred and ninety-one miles by railway, and four hundred and thirty miles by the water conservation surveys, or a total of seven hundred and twenty-one miles.

(5) Commencing at Hay and following lines through Oxley, Booligal, and Hillston, thence along the north side of the Willandra Billabong and through the county of Manara to the Teryaweynya and Tallywalka Creeks and on to Wilcannia and thence up the River Darling to Bourke, the difference with the railway levels at Bourke was 5·07 feet. The distance in this case was nine hundred and fifty-seven miles by railway and six hundred and forty miles by the water conservation levels, or a total of 1,597 miles.

(6) Commencing at Wilcannia and following lines down the River Darling to Wentworth, thence through Gol Gol, Euston, Balranald, Oxley, Booligal, Hillston, down the Willandra Billabong, through the county of Manara to the Teryaweynya and Tallywalka Creeks and thence back to Wilcannia, the water conservation levels showed a closing difference of 2·42 feet for a length of 1,020 miles.

(7) The water conservation levels commencing at Bourke and closing at Wentworth differ from those of the Harbours and Rivers Department by 2·10 feet, the circuit consisting of eight hundred and ninety miles by railway, eight hundred and fifty miles by the Harbours and Rivers Department, and five hundred miles by the water conservation lines, or a total of 2,240 miles.

(8) Commencing at Bourke and carrying levels up the River Darling to Walgett, the difference at the close was 1·68 feet, the distance being three hundred and seventy miles by railway, and two hundred and twenty miles by the water conservation levels, or a total of five hundred and ninety miles.

(9) Commencing at Bourke and following lines up the Rivers Darling and Namoi to Narrabri, the closing difference was 1·33 feet, the circuit representing eight hundred and fifty-three miles

by railway and three hundred and fifty miles by the water conservation lines, or a total of 1,203 miles.

(10) Commencing at Narromine and following lines down the Macquarie and Bogan Rivers to Bourke, the closing difference was 1·22 feet, the distance being two hundred and three miles by railway and three hundred and ten miles by the water conservation levels, or a total of five hundred and thirteen miles.

(11) Commencing at Narromine and following lines to Walgett the close with the levels of the Railway Department shows a difference of 1·51 feet, the circuit including one hundred and forty miles by railway levels and two hundred miles by the lines of the water conservation surveys, or a total of three hundred and forty miles.

(12) Commencing at Narrabri and following lines down the River Namoi and then up the Darling and Gwydir Rivers to Moree, the difference at the close was 1·71 feet, the circuit including seventy miles of railway levels and two hundred and sixty miles by the lines of the Water Conservation Branch.

Other instances of closes of large circuits of an equally satisfactory character might be quoted, but enough has been stated to shew that in the first place the levelling was carried out with every attention to accuracy, and in the second place a complete examination of the books was made and all available checks brought into operation. Nearly all the large circuits comprise work done by two or more surveyors working separately, and in some cases at entirely different times. The only reduced levels supplied to surveyors were those of starting points, but where circuits of any considerable extent were completed, the surveyors reported the result and notice was sent to them as to whether the close was satisfactory. Every set of books was examined directly it was received and before any payment was recommended on account of work done. Any part of the work which was not up to the standard of accuracy, or which failed to furnish the information required in the printed regulations or in the special

instructions, had to be dealt with fully in the field before a final settlement for the work was made. As already indicated, cases of this kind seldom occurred.

Having stated briefly the circumstances which led to the initiation of the water conservation surveys, and given an outline of the objects in view and of the manner in which the surveys were carried out, it remains to give a summary of the work done and of the information obtained. Stated in the shortest possible terms, what we now possess is a sound knowledge of the levels of every river basin of any importance west of the Dividing Range. The levels form a complete connection between Mungindi and Wentworth, between Boggabilla and Albury, between Wagga Wagga and Wilcannia, and between Cowra and Barringun. In fact, the great central basin of the River Darling and all its tributary basins of any importance in this Colony are traversed by a continuous network of levels. The conditions which govern the supply of water in the lakes, and great natural depression on the River Darling, from Lake Narran on the north to Lake Popilta and the other lakes of the Great Ana Branch on the south, have been investigated. The remarkable facilities which exist for the distribution of the waters of the Murray and the Murrumbidgee for irrigation purposes have been clearly established, as has also the value of Lake Urana and Lake Coolacumpama as storage reservoirs for the surplus waters of the latter river. The practicability of making extensive use of the effluent channels of the Lachlan and the Macquarie has been made evident, and the value of these channels as distributaries of the surplus waters of the rivers has been proved. The conditions of the Namoi and the Gwydir have been investigated, and levels have been taken over possible sites for storage reservoirs on both of these rivers. The system of levels in the Gwydir District has shown conclusively the practicability of draining the great swamps in what is known as the "Watercourse Country." Lake Cowal, Lake Cudgellico, and the smaller lakes on the lower part of the River Lachlan have been connected with the levels and surveys, as have also

Lakes Tala, Yanga, Pitarpunga, Waldaira, and others on the Lower Murrumbidgee and Fletcher's Lake, Gol Gol Lake, and Lake Benanee on the Lower Murray.

Among isolated surveys may be mentioned that of Tantangra Basin on the Upper Murrumbidgee, while Lakes George, Bathurst, and Victoria have also been investigated as regards their levels and conditions.

The levels which were taken from the River Lachlan along the course of the Willandra Billabong and thence to the River Darling, connecting with the series of lakes on the Lower Tallywalka, threw much light on the subject of the feasibility of storing flood waters in that dry district.

To illustrate the value of the surveys which have been made, two points in the history of irrigation in the Western States of America may be referred to. The first is that when landowners and speculators discovered that extensive water rights could very easily be acquired, they proceeded to construct irrigation canals with such haste that sometimes the surveys were very imperfect, and sometimes no surveys were made. The result of this was that not only were works carried out on wrong lines, but it sometimes happened that several separate canals were constructed where one canal would have served the purpose in view, and would have avoided the waste which a number of separate canals entailed. On this subject any one who wishes to have further information, should refer to the report of Mr. Deakin, formerly Chief Secretary of Victoria, who was a friendly though candid critic of American works and methods.

The second point to which I wish to refer in connection with American irrigation, is the fact that the Central Government of the United States decided to carry out an elaborate and very extensive system of water conservation surveys, and that these surveys have been in progress during the past six years. This is a complete departure from the policy almost invariably adopted in that country of leaving everything to private enterprise. A very dearly bought experience in the Western States had shown

that in connection with works for water conservation and distribution, complete and reliable surveys are indispensable.

Already the negative value of the surveys carried out in this Colony has been far greater than is generally supposed. They have furnished a ready means of disposing of many impracticable proposals, the mere enquiry into which would have entailed considerable expense. The positive value of the surveys has also already been much greater than is generally known; but their importance will only be realised as works proceed. Meanwhile they indicate what *can* be done in regard to the distribution of the available supply of water in the western rivers, and also, to an important extent, what *can* be done to supplement this supply. It remains to be decided what *should* be done.

Discussion.

Mr. G. H. Halligan said that Mr. McKinney's paper might be said to have been the first contribution in this country, to a subject which had engaged a great deal of attention, and had provoked a large amount of discussion in other parts of the world. Although the literature of the subject of "spirit levelling" was large, it was so scattered amongst various reports and contributions to scientific societies, that it was very difficult to obtain comprehensive information on the matter. On a subject which appears so simple, it was at first sight, surprising that so much had been said and so much ingenuity expended, when to a superficial observer such results as Mr. McKinney enumerated could be obtained by ignoring the more delicate and intricate appliances generally thought necessary by levellers in other countries. For when the circumstances were taken into consideration, some of the closes recorded in the paper were certainly surprising, and however much might be due to compensating errors, still great credit was due to all the surveyors employed, for the thorough manner in which the work had been performed. By exhibiting the information contained in the paper in tabular form, the full force of this remark would perhaps be more clearly seen.

No.	Distance Levelled. Miles.	Error of Close. Feet.	Error of 1 foot in Miles.	Miles Levelled by		
				Harbours and Rivers	Railways.	Water Conservation.
1	1300	1·56	833·3	850	...	450
2	392	·54	726	...	189	203
3	1394	·50	2788	850	264	280
4	721	2·34	308·1	...	291	430
5	1597	5·07	315	...	957	640
6	1020	2·42	421·4	...	...	1020
7	2240	2·10	1066·6	850	890	500
8	590	1·68	351·2	...	370	220
9	1203	1·33	904·5	...	853	350
10	513	1·22	420·5	...	203	310
11	340	1·51	225·1	...	140	200
12	330	1·71	193	...	70	260
	11640	21·98	529·5			

It would be noticed that the closing errors varied from 1 foot in 2,788 miles in No. 3, to 1 foot in 193 miles in No. 12, while the mean closing error on the total distance levelled amounted to 1 foot in 529½ miles. To the surveyor, this information was of very little value without a knowledge of the country levelled over, and the circumstances under which the levels were taken. On this subject the paper did not touch, the author no doubt thinking that most of his hearers would have a good idea of the class of country traversed, from being residents in the Colony; but in the interests of readers in other parts of the world, it was to be regretted that this information had not been given. In all reports on levelling operations by the Survey Department of India, in the Geodetic Survey of the Cape of Good Hope, the United States Coast Surveys and various other valuable scientific reports, the rises and falls, number of bench marks laid down, and the class of country traversed, were all enumerated as having an important bearing on the subject, and allowing those interested to form an opinion on the value of the close.

It was perhaps unnecessary to state that the value of a line of levels was by no means to be gauged by a knowledge of the closing error only. The writer had on various occasions made the

most unexpected closes on a line of levels most roughly done, while at other times when accuracy was the first consideration, it had been a most difficult matter to obtain a reasonable close. Except in flat country where equal sights could be obtained, it might be said to be impossible to level from morning to night and obtain anything like favorable results, as the refraction element entered so largely into all observations made in the densest part of the atmosphere. As all the work done by the Water Conservation Department, was by contract, it seemed natural to infer that all the daylight would be utilised when possible, and thus when very good closes were made the errors must have compensated in a very fortunate manner. In the survey of India, where the most elaborate precautions were taken to insure accuracy in levelling, and one mile to two miles a day was regarded as good work, where staves were standardized at the beginning and end of each work, and were marked as being one-ten-thousandth of a foot too long or too short, an error of one inch in 356 miles was looked upon as an unusually good close.

The error in No. 3 line of levels, referred to in Mr. McKinney's paper, was equal to one inch in $232\frac{1}{3}$ miles, which might be taken as comparing very favorably with the best work by the best men in the older countries of the world. The average daily rate of progress attained by the surveyors on this work would have been a valuable addition to the paper, and also a statement of the distance between bench marks on the routes. It was only by cross levelling between intermediate bench marks on the various routes, that a true check on the work could be obtained, and this would probably be carried out as settlement extends, and the serious work of water conservation and irrigation is undertaken. That such work will be undertaken at an early date, must be the wish of all who have the interest of this country at heart. The most casual observer, who travelled in the inland plain country was struck with the wonderfully luxuriant growth, where water was judiciously applied to the apparently useless soil. The valuable information obtained thus far by the Water Conservation

Department denoted unmistakeably the immense possibilities of the western division of the Colony, and it was only by such comprehensive surveys that properly thought out schemes could be devised for improving this portion of our estate.

Mr. HAYCROFT said there was very little in Mr. McKinney's paper which admitted of discussion, the information contained in it was of such a general character. Nothing for instance had been said as to the class of instruments used, nor, as Mr. Halligan had pointed out, the number of bench marks and distances between them. There were certainly errors in the closes, whether made by the surveyors of the Water Conservation Department or in existence before the work was taken in hand. As regards the hard and fast rule laid down of one foot in 100 miles, as the closing error, that is not the custom in all parts of the world. The recognised rule in countries where precise levelling is carried on, is that the limit of discrepancy in feet (error of closure) shall not exceed $0{\cdot}012\sqrt{\text{distance in miles}}$; this variation is in accordance with the law of probabilities. Many instances of accurate levelling in America could be cited. In a length of 4,000 miles reaching from New York to Chicago and other cities, the closing error was only one foot, and the cost varied from £3 12s. to £4 4s. per mile. In the levelling carried out in St. Louis a circuit of 240 miles closed with an error of only 0·001 foot per mile.

The German practice is very exacting, they do not allow actually $\frac{3}{4}''$ in a mile; ·7″ they consider good work, 1·18 inch passable work. It must be understood that this rule is only applicable to short courses: in long courses such as mentioned in the paper the rule would be error of closure in feet should not exceed ·012 multiplied by the square root of the course in miles. Thus in Case 5, mentioned in Mr. McKinney's paper, where the error of closure is given as 5·07 feet in 1,597 miles, good Continental or American practice would only permit of 0·48 feet. As regards Mr. McKinney's reference to errors made in the western parts of America, he thought that the rest of the world had a good deal to learn from American practice in these matters; and it must

be borne in mind that in one sense the making of mistakes was the initial stage of experiment; no doubt the errors referred to had been made by land owners and agents. The Yankees were cute enough to see the benefits of irrigation, and at the present time he believed there was more irrigated land in the United States than there would be in Australia at the close of one hundred years. It would appear from Mr. McKinney's paper that no summit levels are fixed, and it is imposible to say from the paper how the levels referred to can be utilised for water conservation.

Mr. DAVIS said that on the paper as a whole he had not much to say, but as regards the question of datum, Mr. McKinney said the datum adopted was taken from the Railway Department, *i.e.*, Sydney high water mark. From his experience in levelling he had found that the Sewerage Department datum did not correspond with that of the Railway Department, and again the Railway Department did not agree with the Survey Department. The want of uniformity was a great hindrance in all classes of engineering work, and it would be a good thing accomplished if the different departments could agree upon a common starting point in this matter.

Mr. J. B. HENSON said that it would be interesting to know whether, from the numerous surveys which had been made, sufficient information was obtainable to enable a rough contour map of the western slopes of the Colony to be prepared. A general contour map of a locality was indispensable in the designing of sewerage and drainage works, and the usefulness of a contour map of the Colony not only in relation to the designing of water conservation and irrigation schemes but for other purposes, was unquestionable. Money expended in the production of such a map would be wisely applied, and if a scheme for contouring the whole Colony had not yet been projected the time had arrived for taking action in this matter, and a procedure might be arranged for embracing the future surveying and levelling done by each branch of the public service.

Mr. C. J. MERFIELD said that Mr. McKinney mentioned in his paper, that the limit of error allowable by the Government Department over which he had control was not to exceed one foot in one hundred miles. He would would like to ask Mr. McKinney by what method or equation he would represent the error to be allowed in a short distance, say one mile. The United States Coast and Geodetic Survey, and other large departments of survey adopted an equation that varied as the square root of the distance to represent the limit of error; for example in the U. S. Coast Survey the limit of discrepancy in feet between duplicate lines, was not to exceed $0{\cdot}029\ \sqrt{M}$, in which M equals the distance in miles, so that for a distance of one mile this equation would give 0·029 as the limit of error allowable, in a distance of one hundred miles the limit would only be 0·29. Such a result could not be expected under the conditions that levelling was performed on the surveys conducted by Mr. McKinney, indeed it could not be expected. Further, the function that was universally adopted for measuring the relative accuracy of different sets of observations was as follows

$$R = \pm\ 0{\cdot}6745\ \sqrt{\frac{\Sigma\,[v\,v]}{m(m-1)}}$$

in which R equals the probable error of the mean, m equals the number of observations; if $v_1\ v_2\ v_3$ etc., is put to represent the residuals obtained by subtracting the several results from the mean, then $\Sigma\,[v\,v]$ will be the summation of the squares of these residuals. If there are but two observations this formula reduces to

$$R = \pm\ \tfrac{1}{3}\ V$$

in which V equals the discrepancy between the two results. No doubt many of the members present would be familiar with these equations, which were deduced from the theory of least squares. The discrepancy which Mr. McKinney shewed between certain lines of levels certainly gave an idea of their accuracy, and shewed that the work must have been conducted with care. Mr. McKinney was to be complimented for fixing some standard of accuracy such as he mentioned.

Mr. C. W. DARLEY, Engineer-in-Chief for Public Works, remarked that it was highly gratifying to find that the levels taken by the Department of Harbours and Rivers along the river Murray more than twenty years ago, had proved to be so accurate, and had afforded so useful a means of checking the water conservation levels taken in recent years. It spoke well too for the manner in which the work was conducted, that many of the bench marks were still available and in a good state of preservation. He was under the impression that a great part of the work was done by very junior officers of the department.

Mr. MCKINNEY in replying to remarks which were made said that Mr. Halligan's contribution to the discussion was more supplementary than critical, and he quite concurred in the opinion he expressed, that the tabular statement which he prepared from the information in his paper placed in a clearer light the results of the closes of the circuits referred to. In regard to the omission to mention the nature of the country through which the lines were levelled, he assumed, as Mr. Halligan suggests, that those present had a fair general knowledge of this point. As the question had been raised, he might state that as a general rule the lines were through plain country, the outline being varied at long intervals by creeks and sand ridges. Bench marks were fixed at every half mile, and occasionally at important points in addition. With regard to Mr. Haycroft's remarks, there was one point in which he appeared to have misunderstood the author. This referred to mistakes made in Western America. The abstract of Mr. Haycroft's remarks conveyed the impression that surveys for American irrigation works had been described as inaccurate. If Mr. Haycroft would refer to the paper, he would find that what was stated was that in the early days of irrigation enterprise in the Western States, surveys were in some cases dispensed with altogether, and were in other cases very incomplete, and that serious losses had arisen from these causes. He was well aware of the remarkable development of irrigation in the Western States and of the conditions which stimulated it, but there was abundant

evidence that much mischief was done from the causes described. There was, in fact, at the outset a large amount of amateur engineering and surveying in connection with the earlier irrigation work in America, and he thought that Mr. Haycroft would concur in the opinion that in the case of works of any considerable magnitude, this was an unsafe mode of proceeding.

Mr. Davis raised an important question regarding the datum adopted. There could be no doubt, as Mr. Davis stated, that there should be a uniform datum for all levels throughout the Colony. That adopted for the Water Conservation Surveys was the most convenient under the circumstances; but he was of opinion that a better datum would be mean sea level. However, that is a point of less importance than uniformity. In regard to departures from uniformity, if he mistook not, the Sewerage Construction Branch, which was under the charge of Mr. Davis, was the last to adopt a new datum.

With regard to Mr. Henson's inquiry, Mr. McKinney pointed out that a contour map of Southern Riverina was published in 1891, the contours being five feet apart vertically. Contour maps of the Macquarie, Castlereagh, Namoi, and Gwydir districts have also been prepared and parts of them published.

In reply to Mr. Merfield's inquiries as to how errors in short distances were dealt with, it was explained that questions regarding errors in short distances very seldom arose. When they had to be dealt with, they were considered on their merits—if the error was materially above the limit the work was done over again and if the error was not much above the limit and the general character of the work was satisfactory, the short length exceeding the limit of error was allowed to pass.

With regard to the remarks of Mr. Darley, it was explained that a large proportion of the water conservation levels was checked by the surveyors going twice over the lines. Mr. McKinney added that he had reason to believe that the levels taken many years ago by the Department of Harbours and Rivers from Albury to Wentworth were checked in a similar manner—a junior officer of the party employed being required to go over the lines independently and compare notes as the work proceeded.

LIFT BRIDGE OVER THE MURRAY AT SWAN HILL.

By PERCY ALLAN, Assoc. M. Inst. C.E., Assoc. M. Am. Soc. C.E.

[With Plates 1 – 4.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, November 18, 1896.*]

THE Lift Bridge over the Murray River at Swan Hill having just been completed, and the author having in 1894, under Mr. Hickson, M. Inst. C.E, then Engineer-in-Chief for Public Works for New South Wales, designed the structure, has the honour of placing before the members of the Section a description of the work—before entering on the subject of the paper, it seems desirable to briefly refer to the character of the river traffic to be provided for, and the considerations leading to the adoption of lift bridges—whilst a short resumé of the lift bridges previously erected in the Colony, may be of interest.

The report by Mr. Darley, M. Inst. C.E., Engineer-in-Chief for Harbours and Rivers in 1890, on the Locking of the Darling, conveys an idea of the large traffic using the great rivers of the Colony, the number of steamers and barges trading on the Darling and Murray Rivers being given as two hundred and twenty-two, with a total net tonnage of 20,358. The traffic consists mostly of steamer with barge in tow carrying in some cases 1,000 bales of wool. The largest steamer of which the author has a record is 123′ long, carrying a width of 33′ 6″ over sponsoons, and requiring a minimum headway of 28′ when flying light, this vessel trading between Swan Hill and Mildura on the Murray River.

The considerations leading to the adoption of lift bridges for the Darling, Murray and Murrumbidgee Rivers my be summarised thus :—

1. Economy.

2. The absence of masted vessels doing away with the necessity of an uninterrupted headway, as afforded by a swing span or bascule.

3. Narrowness of "low rivers" rendering pivot pier in centre of stream objectionable.

4. The necessity of providing the maximum headway in the highest floods.

5. The low lying land on either side of river necessitating long approaches to a fixed bridge with the required headway.

6. Heavy wool teams on a narrow bridge making long graded side spans inadmissible.

The first two lift bridges in the Colony were erected in 1880 at Bourke and Balranald, on a design by Mr. J. H. Daniels, Assistant Engineer, acting under the late Mr. W. C. Bennett, M. Inst. C.E., Commissioner and Engineer-in-Chief for Roads and Bridges, and in 1885 the author acting for Mr. J. A. McDonald. M. Inst. C.E., Engineer for Bridges, then absent in England on leave, designed under the late Mr. W. C. Bennett, the lift bridge over the Barwon River at Brewarrina, erected by day labour under the supervision of the late Mr. John Coleman, Resident Engineer at Bourke, at a total cost of £7,700. The bridge consists of a steel lift span on iron cylinder piers, giving a clear fairway of 47′ 6″ with timber side spans, making a total length of 267′ between centres of abutments, the clear headway provided when lift is raised to its full height being 22½′ above highest flood.

The two steel main girders of lift span are of light construction, the booms being each formed of two angle bars back to back riveted to 9″ × ⅜″ boom plates, the web being formed of diagonal channel struts and flat diagonal bars, the steel web plate cross girders 1′ 6″ deep pitched 4′ 6″ apart, are riveted to bottom flange of main girders, whilst steel web plate frames are placed between the cross girders to shorten the span of the 3″ sawn planking forming the floor of bridge. A lateral system of diagonal tie rods is secured to bottom booms of main girders which materially "stiffens" the lift span when being raised or lowered.

The iron hollow towers at the four corners of the lift span let 3′ into cylinders and surrounded for this depth with concrete, are connected at the top by transverse and longitudinal girders, thus preventing the tops of towers approaching one another and jambing lift span when being raised. Four short galvanised link chains attached to the top boom at each end of main girders, pass over chain wheels placed at the top of each tower, and are then secured to cast-iron balance boxes inside the towers adjusted with lead filling; chains are attached to the bottom of balance weights, pass under sprocket wheels at the foot of towers and are secured to bottom corner of each main girder, thus making practically an endless chain and leaving bridge balanced in any position, the weight to be lifted being only that due to friction.

The bridge was designed to be operated by two men each working a winch placed on a platform on the downstream side of each pier, driving a transverse shaft to which are keyed the two sprocket wheels in the bottom of each pair of towers, whilst uniform lifting of ends of span is ensured by connecting the chain wheel at top of tower with bevel gearing. The ratio of gearing is sixteen and a-half revolutions of handle to one of chain wheel; permitting of bridge being lifted to its maximum height of 19′ by two men in four and a-half minutes, or at the rate of 4·22′ per minute.

In 1895 the Bourke bridge was altered so as to permit of one man instead of two, working the lift span. Contracts being subsequently let for similar alterations at Brewarrina and Balranald. The alterations consist in the substitution of wire ropes for the four suspending chains, the arrangement of the ropes being designed by Mr. de Burgh, M. Inst. C.E., and may be shortly described as follows:—

From each corner of lift span a wire rope passes over and around a rope wheel at top of tower, thence across the span and over the rope wheel on the opposite tower, the end being then connected to balance weight, the ropes from each corner of lift span thus crossing one another at centre of span. The bridge is

raised and lowered by means of one winch driving the two sprocket wheels, working two chains attached to the bottom of the two weights (over one pier) and is then secured (after passing under sprocket wheels) to bottom corners of lift span.

In 1889 Mr. J. A. McDonald, M. Inst. C.E., Engineer for Bridges for New South Wales, introduced a new design for the Mulwala Bridge over the Murray River, the author working out under Mr. McDonald the details in connection with the structure, this design being repeated for the Wentworth Bridge over the Darling River, the clear fairway provided is 46′ 3″ and the clear headway above highest flood being 23′ 4″. The leading features of this design were—the stiffening of superstructure by the better disposition of the materials, the substitution of wire ropes for the cumbersome chains previously used, the placing of the operating winch overhead at the centre of the lift span, and the arranging of the winch so that the one main longitudinal shaft geared directly with the two transverse shafts carrying the rope wheels. The design was far in advance of previous lift bridges but difficulties were met with owing to the untwisting of ropes causing the weights working in the towers to brush, inducing considerable friction, which it was thought advisable to avoid when the Wilcannia and Tocumwal Bridges, designed by Mr. J. A. McDonald, under Mr. Hickson, were being considered.

In the design for these two bridges the driving shaft was placed transversely and geared into two longitudinal shafts carrying the rope wheels placed directly over the centre of the towers, the balance boxes being placed on the outside of towers working on V guides. The clear fairway provided is 50′ 5″ and clear headway above when span is raised full height being 25′.

The Swan Hill bridge designed by the author in 1894, was the next and latest type of lift bridge to be erected. The bridge consists of one steel lift span 58′ 4″ between centres of bearings over piers, two 91′ 6″ timber truss spans, and four 35′ timber approach spans. (*Plates* 1 and 2.) The bridge is designed for a

live load of 84 lbs. per square foot of floor space, and a concentrated load of $16\frac{1}{2}$ tons on a 10′ 4″ wheel base, with $9\frac{1}{2}$ tons on a pair of wheels, 5′ centres. The wire ropes carrying counterweights are $2\frac{1}{2}$″ circumference composed of six strands round a core of hemp, each strand containing seven wires of mild crucible steel, having after galvanising, an ultimate strength of 87 tons per square inch, and a twisting strength of 34 turns in a length of 8″.

Prof. Warren, M. Inst. C.E., has carried out at the University of Sydney for the Bridges Branch of the Public Works Department, a number of tests on rope of the same section, the results (given in appendix A.) showing the ultimate strength of a full size "laid" rope to be 90% of the strength of the forty-two wires tested individually, and the strength of a turned and spliced end to be 83% of the ultimate strength of the rope. As the ultimate strength of the sixteen ropes in Swan Hill bridge is 266 tons, and the weight of lift span only $34\frac{1}{4}$ tons the ropes have a "factor" of $7\frac{3}{4}$, an ample margin in view of the slow speed and large diameter of the rope wheels, the wheels being seventy-seven times the diameter of the ropes.

The steel used in the superstructure is of a mild quality, having an ultimate strength of 26 to 29 tons per square inch, with an elongation of from 20% to 26% in a length of 10″. The main girders of steel lift span stand 16′ 4″ apart and have sliding bearings at each end, whilst the timber trusses are 21′ 7″ apart centre to centre. The 4″ sawn tallow wood planking on the lift span rests on longitudinal ironbark girders secured to steel web plate "fish-bellied" cross girders pitched 8′ 4″ apart.

The planking on truss spans and approach spans rests on ironbark longitudinal girders. The carriage way is 14′ between the sawn ironbark kerbs on lift span, and 18′ 3″ and 21′ 11″ between kerbs on truss and approach spans respectively, one 4′ 6″ foot way being provided on the upstream side of truss and approach spans.

The two river piers each consist of a pair of cast-iron cylinders 18′ 4″ centre to centre, founded on rock and extending to a height

of 1′ 8″ above summer level, supporting two wrought-iron cylinders 6′ diameter, connected with stiff wrought iron diaphragm bracing, so designed as to ensure pier acting as a whole. The cylinders are filled with concrete composed of five parts of $2\frac{1}{2}$″ granite, two parts of sand and one part of Portland cement, richer concrete being used in the top and bottom of cylinders. The maximum pressure on the rock foundation with bridge fully loaded and neglecting any assistance from flotation being $4\frac{3}{4}$ tons per square foot.

The superstructure of lift span is similar to that adopted for the Tocumwal and Wilcannia bridges, the two steel main girders are 4′ 2″ deep with top and bottom boom of trough section, formed of two angle bars riveted to 12′ × $\frac{5}{16}$″ plates, the web consisting of vertical struts at ends and channel bars set to an angle of 45°. The steel web plate cross girders are placed at the apices, being carried on steel saddle plates riveted to bottom boom of main girder, two main girders being connected by a lateral system of adjustable diagonal flat bars. The side spans are of the 1893 standard type design, a description of which has already been given by the author in a paper read before this Section.[1]

The four hollow towers (similar in general design to Tocumwal bridge) 3′ square, 40′ 2″ long, are formed each of four vertical angle irons, braced with horizontal T iron and flat diagonal tie bars. The base of each tower is continued 6′ down inside wrought iron cylinder and bolted to four 6′ lengths of vertical angle iron, these vertical angle irons being bolted to diaphragm plates, which in turn are connected to the shell of cylinder by 3″ × 2″ × $\frac{1}{2}$″ angle irons with $\frac{3}{4}$″ rivets, the base of the tower being then filled in with concrete to the level of cylinder caps; the bolt holes in the 6′ vertical angle irons and in the diaphragm plates were drilled *in situ*, thus permitting of the adjusting of the slight difference in the sinking of cylinders, which amounted to $\frac{1}{8}$″ in the centres of the upstream and $\frac{7}{16}$″ in the centres of the downstream cylinders.

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[1] Journ. Roy. Soc. N. S. Wales, Vol. XXIX., 1895.

A provision for such adjustments (*Plate* 3, fig. 1) is of considerable importance in this type of bridge, the correct centring of towers being specially necessary for the satisfactory working of lift span. Over each pier are seated two transverse girders spaced 17″ apart, the webs being connected with four diaphragms, and the top and bottom flanges, with chequered plates and flat diagonal bars respectively. Between the transverse girders over each pier, are fitted, two longitudinal girders spaced 13′ 7″ apart. A lateral strut at centre of longitudinal girders with four diagonal tie rods completes bracing of the tops of the four towers. (*Plate* 4)

The lift span is counter weighted with four cast-iron balance boxes, working on steel V guides bolted to the outside angles of towers. (*Plate* 3, fig. 2) The balance boxes (each in eight sections, filled with lead) are carried by wrought iron adjustable suspension rods, to which are spliced the sixteen $2\frac{1}{2}$″ steel galvanised wire ropes—four to each box—which pass over the rope wheels placed over the top of towers and are then connected to steel suspension brackets bolted to the four corners of lift span. The lift span "hangs" clear when being raised, but provision is made for "swaying" by placing two rollers at each corner of span to take bearing on a bull headed rail bolted to angle irons of towers. The machinery platform (*Plate* 3, fig. 2) is placed downstream at the same level as kerb of side spans.

Although provision is made for working with two men, the bridge as a rule, will be operated by one man working a winch-handle (*Plate* 3) on a horizontal shaft inside the towers, carrying a pinion gearing into a spur wheel keyed to a second horizontal shaft which is connected by mitre wheels to a vertical shaft passing up the inside of and through the top of towers, the vertical shaft being connected by bevel wheels with a short horizontal shaft at the top of towers, (*Plate* 4) carrying a pinion gearing into a spur wheel keyed to the downstream longitudinal driving shaft, to which is keyed at each end a pinion gearing into teeth cast on the inside of rim of the two rope wheels over down-stream towers, pinions are also keyed to ends of upstream longitudinal shaft,

gearing into the two rope wheels over upstream towers, whilst the two longitudinal shafts driving the four rope wheels are connected by mitre wheels keyed to a transverse shaft, the uniform working of lift span being thus ensured.

The total weight of the lift span is thirty-four and a-quarter tons, and is so far counterweighted that a maximum weight of 1800lbs. has to be raised or lowered, one man with ease raising or lowering span through 25′ 10″ in $5\frac{1}{2}$ minutes or at the rate of 4·7′ per minute.

It may be here noticed that the Brewarrina bridge with its "endless" chain is balanced in all positions, but at Swan Hill the lift span is only in balance when opposite the counterweights, necessitating provision being made in the latter bridge for lifting the unbalanced ropes, this weight however is more than compensated for by the reduction in frictional resistance obtained with ropes in lieu of chains and sprocket wheels.

The Swan Hill bridge differs from previous lift bridges in this Colony, in which wire ropes have been adopted, in the following respects—the lift is 5′ 10″ higher, the machinery platform is placed at deck level thus avoiding the time lost by man climbing towers and making his way to an overhead winch, whilst the disposition and design of lifting gear is altogether new, again the absence of an overhead machinery platform relieves the deep longitudinal girders in the Swan Hill bridge of considerable weight, thus preventing any deflection in the girders, with the accompanying "pinching" of the shafts.

The gearing and shafting throughout the author's design is very much lighter, the pitch of teeth of pinion on the shaft driving rope wheels being only $1\frac{1}{2}$″ as against $2\frac{1}{2}$″ and on the first motion shaft $\frac{7}{8}$″ as against $1\frac{1}{4}$″ in previous bridges.

Again the adoption in the Swan Hill bridge of eight cast-iron boxes filled with lead for each counterweight, in lieu of a balance weight formed of a cast-iron bottom section weighing four and three-quarter tons with a cast-iron top section filled with lead, facilitates

transport and erection, whilst the substitution of lead for a greater portion of the cast-iron used in previous counterweights reduces the overall length of the balance weight with a corresponding reduction in the height of the four towers.

The Tocumwal and Swan Hill bridges, being over the same river, having the same fairway, the same width of deck, the same weight of lift span, and having been erected by the same contractor, a comparison of the relative cost of the two designs may be of interest.

The Tocumwal bridge was completed in 1895 and the Swan Hill bridge in 1896, the distance from Melbourne to site of the former bridge is one hundred and fifty-seven miles (one hundred and fifty miles by rail and seven miles by road), and from Melbourne to Swan Hill two hundred and fourteen miles by rail.

The lift span, towers, overhead bracing girders at top of towers, platforms, counterweights and machinery complete fixed *in situ*, cost for Tocumwal Bridge £3,400 as against £2,600 for the Swan Hill bridge, with its 5′ 10″ additional lift.

The overall length of the Tocumwal Bridge, with the iron side spans is 336′ as against 385′ the overall length of the Swan Hill bridge with timber side spans. The completed cost of the two structures including engineering expenses being £19,635 and £8,900 respectively. The large difference in cost is due to the more economical design of lift, the substitution of timber for iron side spans and the securing of foundations for the two river piers at Swan Hill at a lesser depth than at Tocumwal, again the plant used at Tocumwal bridge, was available for Swan Hill bridge and prices were lower when contract for the latter bridge was placed.

The contract for the bridge and New South Wales approaches was let on 6th June, 1895, to Messrs. J. B. and W. Farquharson of Melbourne, who placed the manufacture of the metal work with Messrs. Mephan, Ferguson & Co. of Melbourne, the whole

of the timber, with the exception of a few piles was obtained from the northern rivers of New South Wales, forwarded to Melbourne by sea, a distance of about 726 miles, thence to site by rail a distance of 214 miles, or a total carriage of 940 miles, the planed and framed timber in truss work being erected *in situ* at 4/- per cubic foot, which gives a clear idea of the economical character of this design of truss. Mr. D. W. Armstrong was the Resident Engineer in charge of the erection of the structure, he having previously superintended the erection of the lift bridge at Mulwala.

In conclusion the author desires to acknowledge his indebtedness to Mr. Darley, M. Inst. C.E., Engineer-in-Chief for Public Works, (under whom the Swan Hill Bridge was completed) for the courtesy extended in lending photographs and supplying plans to illustrate the several bridges referred to in the paper, and to mention the assistance of Messrs. Dare and Edgell, Assoc. Ms. Inst. C.E., who, under the author's direction were engaged on the more important detail work connected with the structure.

SUMMARY OF TESTS MADE AT THE SYDNEY UNIVERSITY FOR ON CRUCIBLE STEEL WIRE

SINGLE WIRE TESTS.

Date of Test.	Test No.	Original Dimensions.			Ultimate Strains.		Estimated ultimate strength of 42 wires based on average of straight wires, tons	Torsional.	
		Diam.	Mean diam. of wires	Mean area of wires.	Totals in lbs.	Average of wires in lbs.		No. of turns in 8 in.	Average No. of turns.
15/5/93	1 A		·0856	·0057549	1050		22·00	32·5	
					1130			33·0	
					1240			30·0	31·16
					1250	1173·33		33·5	
					1070			24·0	
					1300			34·0	
,,	2 A		·0856	·0057549	1175		22·39	30·0	
					1165			32·0	
					1180			31·0	31·75
					1240	1194·16		32·5	
					1130			32·0	
					1275			33·0	
,,	3 A		·0857	·0057684	1325		23·17	30·5	
					1230			31·25	
					1215			32·0	32·04
					1220	1235·83		31·0	
					1225			31·5	
					1200			36·0	
14/7/94	l_1	·074			1150			38·00	
,,	l_2	·078			1100			38·00	
,,	l_3	·080			1180		21·91	36·00	
,,	l_4	·080	·079	·0049	1200	1168·57		32·00	34·6
,,	l_5	·080			1170			33·00	
,,	l_6	·080			1195			33·50	
,,	l_7	·080			1185			32·00	
7/8/96	A_1	·09			1350			38·00	
		·09			1275			32·00	
		·089			1292			29·00	
		·09	·0898	·04433	1255	1303·85	24·44	32·00	31·3
		·09			1310			31·00	
		·09			1315			29·00	
		·09			1330			28·00	
7/8/96	A_2	·09			1345			27·00	
		·089			1290			31·00	
		·09			1285			28·00	
		·09	·0898	·04433	1195	1272·85	23·86	32·00	31·4
		·09			1290			34·00	
		·09			1305			35·00	
		·09			1200			33·00	

1224·76 Mean. 22·96 Mean. 32·04 Mean.

BRIDGES BRANCH, PUBLIC WORKS DEPARTMENT, N. S. W.,

ROPE, (GALVANIZED.)

FULL SIZE ROPE TESTS.

Date of Test.	Test No.	Description of Rope.	Area of steel in rope.	Ultimate strength of rope in tons.	Ultimate strength of rope = ... per cent. of estimated strength of 42 straight wires.	REMARKS.
15/5/93	1 A	2½" Circumference formed of 7 strands of 6 wires each, round a hemp cord.	·2417058	20·53	93·32	
„	2 A	ditto	·2417058	21·54	96·20	
„	3 A	ditto	·2422728	18·97	81·87	
				20·69 Mean.	90·19 Mean.	
14/7/94	1	2½" Circumference 6 strands of 7 wires each.	·206	19·64	89·64	
7/8/96	A_1	ditto		20 44	83·63	
7/8/96	A_2	ditto		23·03	96·52	

FULL SIZE ROPE WITH SPLICE.

Date of Tests.	Test No.	Description of Rope.	Area of steel in rope.	Ultimate strength of rope in tons.	Ultimate strength of splice = ...per cent. of full size rope.	REMARKS.
5/7/89		2½"Circum.	0·27014	23·66	83·01	
Date of Test.	Test No.	Description of rope.	Area of steel in rope.	Ultimate strength of rope in tons.		
25/9/89	1	2½"Circum.	·27014	19·64		

Discussion.

Mr. Burge said, there was one point he would like to mention, —Mr. Allan in comparing the cost of the bridge at Swan Hill (£8,900) with that of the bridge erected at Tocumwal (£19,635), gave as reasons for the saving on the former, that the plant used at Tocumwal was available for Swan Hill, and that the prices (he presumed wages was meant) were lower when the latter bridge was placed. Now, this comparison having been made he thought the qualifications should have been detailed, and he thought that Mr. Allan might have given a rough estimate as to the difference caused by the fall in wages between the two periods when these bridges were built, and also divided the cost of the plant. Without at all events a rough idea of the qualification, the comparison was absolutely useless.

Mr. Haycroft said that he was not aware whether in this Colony temporary openings in bridges had been effected by other means than lift bridges similar to that at Swan Hill, but if such was not the case, he did not agree entirely with the six considerations put forward by the author which led to the adoption of the lift bridge at Swan Hill.

Taking the first of these considerations, that of economy, this essential could have been better secured by the adoption of a bascule opening with a single leaf; the economy of course was confined to the cost of construction as the cost of working, though not the labour as measured by the work done, would be equal in either case.

The author would no doubt acknowledge that for equal spans it required less power to operate a bridge of the bascule type than any other kind; the average lift of a bascule leaf being only one-half, or it might be, if not necessary to bring it into a vertical position, one-quarter that of a straight lift bridge of equal span. A bascule leaf could be constructed to operate without the aid of towers by counterweighting the end, labour of opening being confined to overcoming inertia and friction as in the case of a vertical lift bridge. He might remark that the bascule type of opening

was probably the oldest type known, having been used in crossing moats, affording a thoroughfare when down and a protection when up.

Consideration No. 2 was rendered unnecessary if No. 1 was proved incorrect.

No. 4 can be equally as easily provided in either type, as also Nos. 5 and 6.

In *Engineering News*, No. 19, Vol. XXXVI., a leader on the design of moveable bridges said, amongst other interesting matter, "It is true in engineering work as in every other industry, that the force of precedent and custom is exceeding powerful and often leads to the adoption of a certain pattern or type of structure or machine, not because it is the best that could be devised, or that is offered, but because custom has sanctioned it and anything else is an innovation." These words were no doubt true in a general sense but he did not consider that they applied to the author, as he gave him credit for being free from such fine old, crusted, conservative feeling.

There was no doubt that the vertical lift bridge, as described, was counterbalanced effectively when being operated, but this very desirable essential could be effected, and has been, in a variety of ways, in a bascule opening.

The author in describing the alterations to the Bourke Bridge in 1895 stated the arrangement of the wire ropes was designed by Mr. de Burgh, and then proceeded to describe the arrangement; after a careful perusal of this description, Mr. Haycroft was of opinion that it was practically identical with the arrangement of the wire ropes used by J. A. L. Waddell, M. Am. Soc. C.E., in the Halstead Street Bridge at Chicago: a very full description of of this structure would be found in the Transactions of the American Society of Civil Engineers, Vol. XXXIII. Mr. Waddell having read his paper in Nov. 1894. He possessed blue prints of the drawings of this bridge, kindly sent him by Mr. Waddell, where of course the arrangement of ropes was similar to that described in the volume referred to.

If the author's statement was correct he thought that the coincidence was remarkable, and he also noticed that Mr. Williamson, M. Am. Soc. C.E., had used an identical device in a design which he submitted for the Newtown Creek Bridge, Brooklyn, N.Y.

Mr. Haycroft would wish to add, that the author was to be congratulated on the type of side spans referred to by him as the 1893 standard type, and there could be no doubt as to the vast superiority of this type when compared with the one it supplanted, which was in existence when Mr. McDonald was Engineer for Bridges, the principal improvements being the abolition of the unnecessary diagonal members in the panels, the removal of secondary stress in the bottom boom, and the facility with which decayable parts could be removed with a minimum of interruption to traffic.

Mr. GRIMSHAW said he found, on reference to the paper, that the timber used in this bridge was obtained in New South Wales and carried a very considerable distance. This struck him as rather remarkable, seeing that abundance of red gum was obtainable near the site of the bridge. No doubt the particular timber used was specified for and this would account for it, but he thought red gum could be obtained in the neighbourhood of Swan Hill at 2/6 or 3/-. He noticed also that the ironwork was constructed in Melbourne, and it might be explained how Melbourne firms secured it against English competitors and if tenders were invited in the old country.

In regard to the design it was of course very evident that this was just the place for a bridge of this description, there being no high masted vessels to go under it. As regards the reduced cost of the Swan Hill bridge as compared with that constructed at Tocumwal, this was no doubt to be accounted for in the shallower foundations and the fact that the plant used for the latter was available for the former. With regard to the reference made to the similarity of design in the bridge under discussion and the Chicago bridge, it was of course quite possible that two engineers should hit upon similar designs at the same time.

Mr. DARE, referring to Mr. Haycroft's remarks on bascule bridges, without wishing to trench on Mr. Allan's reply, was of opinion that the bascule type was unsuitable for rivers such as the Murray, where a bridge had frequently to be opened in flood time, on account of the pressure of water on the tail end of the span when open; in any case, if the additional cost of a pier sufficiently stiff to carry a bascule span were considered, he doubted whether that type would prove economical for a span giving the same clear opening as the lift span at Swan Hill.

Professor WARREN said he would like to ask Mr. Allan in regard to the revolutions of the pinion driving the rope, how much had been allowed for frictional and other prejudicial resistances. He himself had nothing to criticise in the paper. One could see a gradual improvement in the designs of these bridges, as Mr. Haycroft pointed out in the side trusses, and no doubt the lift bridge at Swan Hill was a long way ahead of any which had preceded it.

Mr. ALLAN said, the first point brought forward was by Mr. Burge, that gentleman stating, and with some show of reason, that he (Mr. Allan) should not have compared the Swan Hill Bridge with the Tocumwal Bridge, without showing in detail how the saving in the item of plant, and the reduction in prices affected the comparison. The main feature of the paper perhaps was the lift span, in which a saving was shown of £800, the lift span at Swan Hill costing £2,600 as against £3,400 at Tocumwal—deducting this item for work which is common to both bridges, it leaves the completed cost ef the side spans, piers and approaches of Swan Hill bridge at £7,000 as against £16,255 for the same items in the Tocumwal bridge—this difference was so remarkable, that he (Mr. Allan), considered it unnecessary to go further into figures and show perhaps a 15% reduction in wages, and an advantage at most of a few hundred pounds for plant for the Swan Hill structure. To have made a thorough comparison would have meant going thoroughly into the life of the respective structures and treating the question from a financial standpoint,

however, as this question of the relative economy of Australian hardwood and metal structures had been so exhaustively dealt with by him in his paper on "Timber Bridge Construction in New South Wales," he (Mr. Allan) considered it hardly necessary to again touch upon the question in connection with the side spans of these two structures.

In reply to Mr. Haycroft, he said that several bascule or end lift bridges had been erected in the Colony, of a cheap character. The leaf and towers were of timber, the necessarily varying counterweights being provided for by successively dropping sections of the weights on stops secured within the hollow towers, which were of the same height above top of pier as span of opening; the great height of tower with the pull on the top thereof, consequent upon the raising or lowering of leaf had resulted in the towers "canting" in spite of the tie rods anchoring the top of towers back to the side spans, clearly showing the necessity of a large based tower with this class of bridge, the expense of which, taken in conjunction with the required rigid and costly pier foundations, would be less economical in construction than the straight lift with its additional counterweight, but shorter and lighter towers carrying only vertical loads.

Whilst he was fully alive to the advantages of the bascule for waters carrying masted vessels with small beam, yet Mr. Allan from his experience of opening bridges, was firmly wedded to the straight lift, Swan Hill type, with a certain and direct motion, for rivers where only a limited headway was required.

Mr. Haycroft had referred to the Halstead Street Chicago Lift Bridge, the contract for which was placed in 1893, but it was not until the middle of 1895 that the number of the Proceedings of the American Society of Civil Engineers, containing the account of this bridge, first reached this Colony. Previously to this, provisional protection had been granted to Mr. de Burgh for the arrangement of ropes for the Bourke Bridge, which although somewhat similar, differed from the Chicago Bridge in that the supporting ropes for the Bourke lift span passed from one corner

of lift span over the rope wheel at top of tower, round which the rope takes a complete turn, passing thence across to, and over the rope wheel on opposite tower, the end of rope being made fast to counterweight.

In the Chicago Bridge, the supporting ropes at each corner of span passed over the sheaves at top of tower and were then attached to the counterweights, this being the ordinary means adopted of counterbalancing a lift span, the operating ropes were however crossed over the waterway similarly to the Bourke arrangement, but instead of taking a complete turn over the sheaves, the "turn" was taken over the driving spiral drum at foot of tower, idle pulleys being interposed to change the direction of ropes as required, before attaching to counterweights.

Mr. Allan was pleased that Mr. Haycroft was so thoroughly in accord with him, as to the features of the truss adopted for the side spans of the bridge, which had so far met all that he (Mr. Allan) had claimed for this type of truss when introducing it in 1893.

Mr. Grimshaw had referred to the timber in the structure—Mr. Allan said tallow wood planking and ironbark for the remainder of the work had been specified, it being out of the question, with the small scantlings employed, to use other than ironbark for the truss spans, as will be seen from a glance at the following table, compiled from Professor Warren's work on Australian timbers:

IRONBARK AND MURRAY RIVER RED GUM TIMBER.

AVERAGE STRENGTH IN POUNDS PER SQUARE INCH.

Timber.	Modulus of Elasticity.			Transverse Strength.		
	Specimens tested.	Average modulus.	Excess percentage of ironbark over red gum.	Specimens tested.	Average strength.	Excess percentage of ironbark over red gum.
Ironbark	23	2,635,470	92·6	23	18,204	61·6
Red Gum	3	1,373,542	...	3	11,267	

IRONBARK AND MURRAY RIVER RED GUM TIMBER.

AVERAGE STRENGTH IN POUNDS PER SQUARE INCH.—*Continued.*

Timber.	Tensile Strength.			Compressive Strength.		
	Specimens tested.	Average strength.	Excess percentage of ironbark over red gum.	Specimens tested.	Average strength.	Excess percentage of ironbark over red gum.
Ironbark	15	18.252	121·0	14	10,572	39·5
Red Gum	2	8,258	...	2	7,578	

Timber.	Shearing Strength.		
	Specimens tested.	Average strength.	Excess percentage of ironbark over red gum
Ironbark	16	2,164	43·0
Red Gum	2	1,513	

The experience of the Bridges Branch had been that whilst Murray River red gum was suitable for piles, round girders in short lengths and planking, that when worked into squared timber exposed to the sun's rays, it warped and twisted to such a degree as to render its use in trusses inadvisable, even if its lack of strength did not preclude its use. Although it was optional with the contractor for the Wagga Wagga bridge, he preferred to use ironbark instead of Murray River red gum for piles and round girders, clearly showing it, in that case to be the cheaper timber notwithstanding the long rail carriage of three hundred and ten miles.

With all the Border bridges it was customary to invite tenders for manufacture in either Victoria or New South Wales, Tocumwal bridge ironwork was manufactured in New South Wales, the Swan Hill ironwork in Melbourne, had the tender for Tocumwal bridge, which provided for manufacture of ironwork in Melbourne been accepted, it would have increased the cost of structure by £400. In the Swan Hill bridge alternative tenders were received for colonial manufacture and importation, Messrs. J. B. and W. Farquharson's tender being the lowest in each case, and there

being only a difference of £210 in the prices quoted, the offer for manufacture in Melbourne was accepted.

Mr. Allan agreed with Mr. Dare as to the practical difficulties to be anticipated in working by hand power, a bascule where the local features necessitated the tail end being lowered through the flood waters.

Referring to Professor Warren's remarks *re* the machinery, Mr. Allan said that as the counterweight equalled the weight of the lift span, the only weight to be raised was that due to the unbalanced weight of the ropes, 430 lbs., and the frictional resistance in the journals of the four rope wheels added to the resistance due to the bending of the ropes calculated by Mr. Allan at 1370lbs. making a total pull of 1800 lbs. necessary to impart motion when either lift span or counterweight was on the rests, provision was therefore made in the winch for raising 1800 lbs. Making allowance for the loss due to friction in the winch itself by taking the effective power of one man as 18lbs. applied at the winch handle, the ratio required was thirty-three revolutions of winch handle to one of pinion, the gearing actually provided being thirty-four to one.

CENTRIFUGAL PUMP DREDGING IN N. S. WALES.

By A. B. PORTUS, Assoc. M. Inst. C.E.

[With Plates 5 – 14.]

[*Read before the Engineering Section of the Royal Society of N. S. Wales, October 21, 1896.*]

COMMODIOUS harbours and deep navigable rivers are such important factors in estimating a country's material progress that any description of appliances employed for effecting their improvement must have some interest both for the scientific and commercial members of the community. It is not, however, the object of this paper to deal with the whole subject of harbour and river improvement by dredging, because in doing so the evolution of the ladder and bucket system of river deepening would have to be traced, and to do so would be to tell over again what has been so often and so well told before, viz., the story of the river Clyde, and how, by ladder dredging, it has been transformed from an insignificant stream to being one of the most important arteries of commerce in the British Empire. Readers of the history of the Clyde, the Tyne and the Wear, look in vain for any information about reclamation by sand pumps, because hitherto the centrifugal pump has not, on any of these rivers, been used for deepening purposes, nor had it, with the exception of at Lowestoft, been used at any port in the United Kingdom until the year 1890, when at the Mersey bar it was used with such conspicuous success that the Liverpool Harbour Board, had built, two hopper pumps each capable of lifting 4,000 tons of sand per hour. Some particulars of these vessels will be given at the conclusion of this paper, and also of the leviathan of sand pumps built during the present year on the Mississippi and now pumping on shore silt at the rate of 3,500 tons per hour.

One of the first successful applications of the centrifugal pump (see *Plate* 5) for reclaiming was on the Amsterdam Canal in the year 1867. Before that time, the dredged material was shovelled from the barges into barrows, and wheeled on shore, but such slow progress was made, the canal having to be deepened from 3′ to 23′, that mechanical appliances became almost indispensable, and Messrs. Burt and Freeman fitted to one of the bucket dredges an improved "Woodford" centrifugal pump, the shaft of which worked vertically driving a spinner 3′ 6″ in diameter, fitted near the bottom of an upright cylinder, about 12′ high, so arranged that the contents of the buckets, falling through it, were met by the ascending volume of water from the Woodford pump, and the dredgings, thus liquefied, forced through floating pipes to the shore. The pipes were constructed of wood with leathern joints and were buoyed. As much as 2,000 tons of silt was sometimes thus disposed of in twelve hours and deposited at a height of 8′ above water level at a distance of 1,200′ from the dredge. Dual machines of this type were early in 1870 used in Russia for canal work near Cronstadt. Mr. Burt having further improved the machine by fitting knives on the vertical pump shaft, and by directing into the cylinder water jets under great pressure, succeeded in dealing with stiff clay, and introduced the machine thus perfected on the Danube. In 1880, the Barrow Ship Building Company, constructed for that river a combined bucket and pump dredger 124′ long, 28′ beam, with buckets holding 18′ cubic each, and capable of working at a depth of 28′. The pump was $4\frac{1}{2}$′ in diameter, the pipes were 18″. The engines developed 180 horse power when the buckets and pump were working; how much for each is not stated, but judging from the power required to drive a pump of the size given, the division of horse power was probably 55 for dredging and 125 for pumping.

The machine referred to is, strictly speaking, not a sand pump, but an adjunct, and a most valuable one, to the ordinary ladder dredge. The first sand pump successfully used was employed in Holland about thirty years ago. An old steamer was

availed of for carrying a Woodford pump over the stern of the vessel, the pump was about 3′ 6″ in diameter, fitted in framework hinged to the taffrail, and was lifted or lowered by tackle from a derrick overhanging the steamer's stern ; the pump was usually, when working, near the water, the suction pipe projecting beyond it and of the necessary length to suit the depth of channel required. The pump spinner was driven by the steamer's engine, suitable bevel gearing being applied to permit the suspended framework to be lifted for dredging work. The delivery pipe was fixed so that branches leading on each side to the shores left it at the hinged joint carrying the overhanging platform.

The next stage in the development of the sand pump was its application to steam hopper barges used by Dutch contractors for deepening the seaports of Rotterdam and Amsterdam. This type of sand pump is substantially the kind first used by the New South Wales Government, and instead of describing the twelve self-loading steam hoppers of Messrs. Volker and Bos of Holland, I purpose briefly to refer to the sand pumps "Neptune" and "Juno," (*Plate* 6) vessels used in this Colony for self loading and dumping at sea, as well as for pumping on to reclamation areas original bottom and silt lifted by ladder dredges and brought alongside for putting on shore.

The "Neptune" was originally an iron steam hopper barge of 400 tons capacity, built by Morts Dock Company. The hull was 148′ 3″ in length, beam 24′, and draft light, 8′, and the vessel was used for carrying silt to sea and towing punts in connection with the Sydney ladder dredges.

Until 1888, there was no inducement in this Colony to adopt the system of sand pumping. In Sydney harbour there were no reclamation areas near enough to the channels to permit of floating pipes being placed between the dredge and the shore, while at Newcastle the crowded state of the harbour discouraged the idea, as it does now, of connecting the dredges with the shore by a line of pontoons carrying pipes ; but when it was determined

to dredge out the basin between Bullock Island dyke and Newcastle, the author urged Mr. Moriarty, the then Engineer-in-Chief for Harbours and Rivers, to convert the steam hoppers "Neptune" and "Juno" into sand pumps, and to use them for pumping the sand in the basin on to the areas available for reclamation.

The Government, on the recommendation of Mr. Hickson, acting for Mr. Moriarty, approved of plans of the vessels being sent to Sir John Coode, who arranged with Messrs. J. and K. Smit, of Holland, the principal builders of Dutch sand pumps, to supply the necessary machinery for the alterations. Before the pumps were fitted on board, Mr. Darley, who had succeeded Mr. Moriarty, had the hulls lengthened 12′, to give additional freeboard and to carry more silt, at the same time giving greater space for the machinery. The pump placed in front of the engines is, as will be seen by the drawing, of the simplest possible construction, being in design and action not unlike an ordinary fan or blower. As with all centrifugal pumps a chief element of success is ample driving power. The engines of the "Neptune" are capable of developing 330 indicated horse power, and are of the compound surface condensing type, with cylinders 20 and 36″ and 24″ stroke. Steam is supplied at 80 lbs. pressure by a cylindrical multitubular boiler 11′ in diameter 10′ long, having three furnaces 2′ 6″ in diameter, and one hundred and twenty-eight 4″ tubes. Aft and forward of the engines, suitable clutches are fitted to enable the power of the engines to be almost instantaneously transferred from the propeller shaft to the pump spindle and *vice versa*. Between the engines and the pump a friction nave is fitted, and is adjusted to slip when large pieces of iron or stone are drawn up by the pump, endangering the arms of the spinner. The suction and delivery pipes are 20″ in diameter. The vessel's hopper holds 500 tons of sand, and under favourable circumstances has been filled in nineteen minutes, the engines making 130 revolutions per minute, giving a periphery speed to the 6′ 6¾″ spinner of 2,680′ per minute. These speeds are increased by about eighteen per cent., if the material dredged is sent

through pipes and delivered at a distance of 1,500′ from the vessel. When pumping into the hopper, a much higher percentage of sand is delivered than when the material is sent on shore. Eighteen hundred feet may be taken as the profitable limit for heavy sand, while light silt with the same pump can be discharged at double that distance. The suction pipe of the "Neptune" passes through the vessel's side at about the water line, and a bend outside gives it a direction towards the bow. Between the bend and the long suction pipe a leathern sleeve about 6′ in length is introduced, collapse being prevented by seven or eight iron rings fitted inside seven inches apart. The outer end of the suction pipe is carried by a strong davit, and the flexible leathern sleeve provides alike for lifting the pipe and for surging when the dredge is working in rough water. Thin grating bars about five inches apart are fitted across the mouth of the suction, which is enlarged to about 28″ in diameter.

Well designed steam winches with sufficient barrels, brakes and clutches, are indispensable for successfully working sand pumps. Clark, Chapman & Co. of Hull, make these winches a speciality, the barrels being fitted for stud and short link chain as well as for wire and hemp ropes. To the forward winch the chain for lifting the suction pipe is led, and when working in a channel with the silt being discharged on shore, the same winch works three chains leading to anchors on each bow and to one stream anchor, while the stern winch deals with chains leading aft and upon each quarter. After the pump is started the suction pipe is lowered until the dial on the pump vacuum guage indicates about 12″, when the vessel is moved slowly ahead at a speed governed by signals from the man at the end of the discharge pipe, perhaps 1,500′ away, different coloured discs indicating a sufficiency of sand, or otherwise, in the water passing out of the pipe. Owing to so much sand passing through the pump there is necessarily much wear of surface, and the first casings were fitted wholly with sheathing plates, but it has been found in practice better for the sides to be made of $\frac{3}{4}$″ steel plates, without sheath-

ing, and renew them, keeping always in reserve a duplicate pump to avoid delay. Wear of the bearings is provided for by steel or gun metal bushes, and by a water jet keeping back any escaping sand, The discharge from the pump of the "Neptune" is so arranged that the material can be delivered over the side to port or starboard or into the hopper. Over the hopper and extending throughout its length are two 16″ pipes, fitted with valves underneath to control the exit of the sand and water, which, after leaving the pipes, falls into perforated troughs, the object being to separate the sand from the water. Coombings 30″ high are fitted round the hopper, and the water with some sand flows over the top until the solid material rises to the required height. When hopper loading is being done two anchors only are used, one ahead and the other astern. When reclamation with silt from the "Neptune" and "Juno" was started, much difficulty was experienced with the flexible joints sent from Holland with the pipes, and the author designed the accommodation gimbal joint, shewn on the attached sheet, which permits of greater range vertically and horizontally than even the ball and socket joint, and being very strong has been found specially suited for use in rough water. (*Plate* 7.)

The Dutch type of sand pump just described, although admirably adapted for sand, is entirely unsuited for clay dredging, and we are indebted to American ingenuity for machines fitted for dealing with all kinds of material, among them the "Von Schmidt' and the "Atlas" dredges. Each machine has many admirable features, and both are capable of doing all that is claimed for them. The "Atlas" machine is described and illustrated by Mr. Derry, M. Inst. C.E., in a valuable report to the Victorian Government written in 1885, and improved dredges partly on the "Atlas" principle are fully described in the United States Public Works Guide and Register of 1895. The "Von Schmidt" machine will now be briefly referred to; but persons interested in dredging work should inspect the New South Wales suction dredge "Groper," as that machine embodies all the latest im-

provements in the Von Schmidt type of dredging plant. (*Plate* 8 *and photograph of "Groper."*)

The hull, built at the Fitzroy Dock, is of Oregon pine, and is 115′ long, 50′ beam, and 9′ deep. One end is square, the other semicircular ; the sides are 12″ thick, the ends 16″. Two longitudinal bulkheads, as thick as the sides, extend from bow to stern, and these as well as the skin of the vessel are formed by fitting long 12″ square beams on top of each other until a depth of 9′ is obtained, the whole being tied together with $1\frac{1}{2}$″ drift bolts. The engines, fixed on strong hardwood framing, are compound surface condensing, with cylinders 20″ and $38\frac{1}{2}$″ and 2′ stroke. Steam of 100 lbs. pressure is supplied by two return tube boilers, 10′ 4″ long and 9′ internal diameter, with one corrugated furnace in each 4′ internal diameter, a smaller auxiliary boiler, 6′ 7″ diameter and 9′ 1″ long, is provided for use when silt has to be delivered more than half a mile from the dredge. The pump, with a shrouded cast iron spinner 7′ 6″ diameter, has a wrought iron casing, and is driven at speeds varying from 100 to 130 revolutions per minute, according to the distance the material has to be driven.

The machinery for cutting the clay or other deposits is carried on a strong platform, which traverses on rollers from side to side of the dredge at the semicircular end. At the centre of the semicircle the suction pipe of the pump ascends, and by the intervention of a stuffing box and gland, the outer end of the pipe is enabled to move round horizontally with the travelling platform, beyond which the suction becomes vertical, and terminates in a system of telescopic pipes arranged to deal with the varying depths at which dredging has to be performed. A long vertical shaft is fitted outside of and in line with the telescope pipes and, while the latter telescope, the shaft is accommodated to different depths by passing through the centre of a driving crown wheel, which is operated by a horizontal shaft leading to a special pair of engines working at the centre of the platform. On the lower end of the vertical shaft a horizontal cutter 8′ in

diameter is keyed, with steel knives at its circumference looking both up and down. The bottom of the suction pipe is hooded, extending over the cutter. When the machinery is put in motion, the material broken up by the knives is swept up by the action of the pump through the suction pipe and forced shoreward in the discharge pipes, which are fitted with ball and socket joints and carried on pontoons. On shore the discharge pipe is fitted with a breeches piece and valves, and two pipe lines are afterwards used so that one may be pumped through while pipes are added to the other. The shore pipes are telescope ended, and can be quickly placed to ensure a level reclamation. The overflow water, after passing over an extended settling area, returns to the harbour. Much ingenuity has been displayed by the patentee in arranging by belts, gear, shafting and clutches, the various appliances for lifting and lowering the suction pipe and cutter, and for giving reciprocating movement to the platform. So effective is the cutting mechanism, that a Von Schmidt dredge can cut its way into a bank 3′ above high water just as readily as it can deal with stiff clay or even soft rock at a depth of from 12 to 20′.

The system of mooring the "Groper" for work is that generally adopted in America, viz.: by two long spuds passing through wells and lifted and lowered by steam power from masts placed alongside. I have already referred to the difficulty in carrying out in the past in Sydney Harbour a comprehensive scheme of reclamation at a reasonable cost, owing to the areas suitable for reclaiming being too far distant from the channels to be deepened, and schemes were thought of for pumping the silt out of the punt hoppers; but the difficulty was overcome by dumping the dredgings, in the punts filled by the ladder dredges, alongside a suction dredge, and thus performing the work of deepening at one part of the harbour and reclaiming at another by two machines instead of one. The Dutch type of pump being unsuited for pumping on shore the Sydney Harbour clay, thus dumped, the "Groper" was built at a cost of over £20,000,

about £8,000 of this amount was paid for the "Von Schmidt" pump and machinery and the right to use it. Mr. George Higgins having secured the patent for Australasia, contracted with Mort's Dock Co. to fit it to the "Groper." Although the vessel has been working about three years no favourable opportunity has arisen for testing the machinery at its best effort as far as cost per ton is concerned, because instead of working steadily at original soil the material dealt with has been intermittently dumped alongside, the cost of pumping on shore varying, according to distance, from $1\frac{3}{4}$d. to $2\frac{1}{2}$d. per ton, the cost under the old system of barrows and shovels would, for very short distances, have been from 6d. to to 1s. 2d., while for from one-third to half a mile the price would have been prohibitive.

So much useful work having been done by the suction dredges of the Harbours and Rivers Department at Sydney, Newcastle, and the northern rivers (see schedule attached) the present Minister for Works, Mr. Young, determined to convert a number of grab dredges into small sand pumps. (*Plates* 6 and 9.) Three of them have been so altered, and three others are in course of alteration. The hulls of iron, were cut and lengthened at the Fitzroy Dock works, and special engines, boilers, and centrifugal pumps fitted; the Priestman cranes were retained on board; the jib being availed of for carrying the suction pipe which passes through the bow of the vessel and being fitted with a gimbal joint, the end of the pipe has a considerable range of action, enabling the dredge to cut its way through sand banks uncovered at high tide. If clay or other material unsuited for the Dutch pump is met with, the suction pipe is quickly removed and a grab bucket being attached to the jib chain the Dual machine becomes an ordinary grab dredge. In practice, however, it is found that on our rivers the alteration from pump to grab is seldom necessary, the obstructions to navigation consisting almost wholly of material easily dealt with by a suction dredge. The pump engines in the largest of these combined machines indicate about 180 H.P., the cylinders are 12″ and 24″, supplied with steam at 120 lbs. pressure

by a boiler 8′ 9″ diameter and 9′ long. The centrifugal pump has a spinner similar to the "Neptune," but of only 5′ 6″ diameter, the suction and delivery pipes being 16″ diameter. Pontoons 15′ × 15′ × 2½′ spaced 22′ apart are used, as shown in *Plate* 11, for carrying the pipes to the shore, the arrangement of gimbal and plain joints ensuring sufficient movement of the dredge in all directions for working to the best advantage.

Usually these dredges are worked by making a series of furrows about 50′ in length, until the required width of channel is deepened, but they can also be operated by the crane jib swinging across the channel and trailing, or dragging, the end of the suction pipe; a special mouth piece being affixed to suit this method of dredging,

A very useful modification of the self loading sand pumps of Holland was adopted for deepening Coney Island and Gedney channels in New York Bay, where the water was too rough for using pontoons and pipes.[1] Instead of one pair of engines being used, as on a vessel of the "Neptune" class, alternately for pumping and conveying the sand away, the dredging vessel was fitted with separate machinery for dredging and driving twin screws; and instead of the suction pipe looking forward and being kept up to its work, as in the "Neptune," by a steam winch heaving in chain led to a stream anchor, there were two suction pipes, looking aft, fitted with special mouth pieces for raking the bottom, and hung from framework fixed on each side of the vessel near the stern. The dredge steamed very slowly ahead dragging the ends of the suction pipes over the shoal to be deepened, and the two belt driven centrifugal pumps, working at the same time, generally filled the hoppers containing about 600 cubic yards in forty-five minutes As the work could be only proceeded with in very fine weather, the cost was necessarily high, averaging about **1s. 4d. per cubic yard.**

Dredges of this kind were used in Florida as early as 1871, and they are still used in America for deepening bars where there is

[1] See Trans. American Society C.E., Dec. 1891.

a minimum depth of water, say 10′, to permit of their passing over with the pumps at work at their load draft. In *Engineering* of December last, a vessel of this kind embodying all the latest improvements is described and illustrated.

Recently the New South Wales sand pump "Neptune" dredged a channel a mile in length through the Clyde bar, its comparatively sheltered position rendering the work practicable. Similar dredging, with such a vessel, could not be carried on at exposed bars, such as those at the entrances to the Tweed, Bellinger, Nambucca, Macleay, and the Manning, nor has there yet been built an American bar sand pump capable of deepening such river mouths, because there is not sufficient water on them to permit a ten feet draft vessel loading itself while crossing to sea.

The author intended to refer to the large suction dredges working at the mouth of the Mersey, and to describe the huge machine just started on the Mississippi, but as this paper has become tediously extended, he must ask those interested in dredging to read descriptions of the former in the *Engineer* of October 6th, 1893, and of the latter in the *American Engineering News* of April 2rd, 1896, and in the *Engineer* of 3rd July, 1896.

Recently the Minister for Public Works, on the recommendation of Mr. Darley, M. Inst. C.E., Engineer-in-Chief for Public Works for New South Wales, has approved of an amount being placed on the estimates for the construction of a very light draft twin screw sand pump, arranged to pump sand into its hopper while slowly steaming over the shallow bars of the rivers of the New South Wales seaboard.

STATEMENT OF SAND PUMP EXPENDITURE AND WORK FOR YEARS AS UNDER.

Year.	Sand Pumps.	Where Pumping.	Material Lifted and Discharged on Reclaimed Land.	Estimated Tons Lifted.	Hours Pumping.	Expenditure.	Cost per Ton.	Cost per Hour Pumping.
						£ s. d.	d.	£ s. d.
1890	"Neptune"...	White Bay, Sydney	Sand and Mud	324,440	1,737	2,669 3 6	1·974	1 10 9
1891	„ ...	Do., Snail's Bay, & Leichhardt	„ „	438,204	3,246	4,146 8 1	2·269	1 5 6
1892	„ ...	Leichhardt, Sydney	„ „	524,550	3,497	4,892 16 3	2 238	1 8 0
1893	„ ...	Careening Cove, Neutral and Homebush Bays, Sydney ...	„ „	197,700	1,318	2,368 18 6	2·876	1 15 11
1894	„ ...	Bateman's Bay, Ulladullah ...	„ „	249,000	1,475	3,552 18 9	3·424	2 8 2*d*
1895	„ ..	Do., and Sydney Harbour ...	„ „	309,670	1,383	3,393 6 5	2·629	2 9 0*e*
				2,043,564	12,656	21,023 11 6		
		Average Cost per ton		...	...	... ...	2·469	
		Average Cost per hour		...	...	... ...	...	1 13 2
1890	"Juno" ...	Newcastle	Sand	513,000	2,328	4,674 9 6	2·186	2 0 2
1891	„ ...	„	„	604,608	2,625	3,543 6 4	1·406	1 7 0
1892	„ ...	„	„	554,600	2,773	3,431 4 0	1·484	1 4 9
1893	„ ...	„	„	272,480	1,006	2,572 10 5	2·265	2 11 1*a*
1894	„ ...	„	„	238,400	852	3,023 5 4	3·043	3 11 0*b*
1895	„ ...	Newcastle and Sydney... ...	Sand and Mud	295,410	1,495	2,585 13 11	2·100	1 14 7*c*
				2,478,498	11,079	19,830 9 6		
		Average Cost per ton		...	...	... ...	1·922	
		Average Cost per hour		...	...	... ...	...	1 15 9

a Includes cost of depositing 141,080 tons at sea.
b „ „ „ 174,700 „
c „ „ „ 28,900 „
d Includes cost of depositing 80,700 tons at sea.
e „ „ „ 146,700 „

STATEMENT OF SAND PUMP EXPENDITURE AND WORK FOR YEARS AS UNDER.—*Continued.*

Year.	Sand Pumps.	Where Pumping.	Material Lifted and Discharged on Reclaimed Land.	Estimated Tons Lifted.	Hours Pumping.	Expenditure.	Cost per Ton.	Cost per Hour Pumping.
1891	"Actor" ..	Sydney, and Tweed River ...	Sand	263,600	1,318	3,237 4 8	2·495	2 9 1
1892	„ ...	Womonin Channel, Do. ..	„	484,800	2,424	3,404 4 1	1·685	1 8 0
1893	„ ...	Tweed River	„	303,000	1,515	2,246 8 10	1·779	1 9 7
1894	„ ...	„	„	246,200	1,232	2,629 18 5	2·564	2 2 8
1895	„ ...	„	„	331,812	1,327	1,950 4 3	1·419	1 9 4
				1,629,412	7,816	13,468 0 3		
		Average Cost per ton ...	... ...	...	...	... ...	1·983	
		Average Cost per hour ...	... ...	...	...	... ...	...	1 14 5
1892	"Alesus" ...	Nambucca River	Sand and Mud	303,200	1,516	2,559 7 10	2·025	1 13 9
1893	„ ...	Do., and Macleay River ...	„ „	317,800	1,589	3,297 5 0	2·489	2 1 6
1894	„ ...	Macleay River	„ „	485,300	2,426	3,994 11 2	1·975	1 12 11
1895	„ ...	Macleay and Nambucca Rivers	„ „	461,137	2,614	3,744 16 4	1·948	1 8 8
				1,567,437	8,145	13,596 0 4		
		Average Cost per ton ...	... ...	...	...	... ..	2·081	
		Average Cost per hour ...	... ...	...	...	... ...	...	1 13 4
1892	"Dorus" ...	Myall River, White Bay, Port Stephen	Sand and Mud	296,600	1,483	2,440 11 7	1·974	1 12 11
1893	„ ...	Newcastle, Hunter and Myall Rivers	„ „	274,800	1,374	2,307 1 4	2·014	1 13 6
1894	„ ...	Newcastle, and Hunter River...	„ „	289,400	1,449	2,379 0 8	1·973	1 12 11
1895	„ ...	Newcastle	„ „	312,800	1,564	2,332 11 0	1·789	1 9 10
				1,173,600	5,870	9,459 4 7		
		Average Cost per ton ...	... ...	...	...	... ...	1·934	
		Average Cost per hour ...	... ...	...	...	... ...	...	1 12 2

STATEMENT OF SAND PUMP EXPENDITURE AND WORK FOR YEARS AS UNDER.—*Continued.*

Year.	Sand Pumps.	Where Pumping.	Material Lifted and Discharged on Reclaimed Land.	Estimated Tons Lifted.	Hours Pumping.	Expenditure.	Cost per Ton.	Cost per Hour Pumping.
1893	"Jupiter" ...	Clarence River	Sand	121,100	306	1,880 15 11	3·727	6 2 11*f*
1895	,, ...	Sydney and Newcastle... ...	Sand and Mud	197,890	1,058	2,790 9 5	3·384	2 12 9
				318,990	1,364	4,671 5 4		
		Average Cost per ton ...	... ...	...	...	... ...	3·514	
		Average Cost per hour ...	... ...	...	...	... ...	...	3 8 5
1893	"Dictys" ...	Richmond River...	Sand and Mud	78,600	393	998 11 10	3·049	2 10 9
1894	,, ...	,, ,, ...	,, ,,	337,500	1,688	2,598 8 10	1·847	1 10 9
1895	,, ...	,, ,, ...	,, ,,	301,575	1,235	2,536 10 2	2·019	2 1 1
				717,675	3,316	6,133 10 10		
		Average Cost per ton ...	... ...	...	...	... ...	2·051	
		Average Cost per hour ...	... ...	...	...	... ...	...	1 16 11
1893	"Groper" ...	Callan Park and Leichhardt ...	Sand and Mud	239,250	870	2,572 6 11	2·580	2 19 1
1894	,, ...	Sydney Harbour, Glebe Point...	,, ,,	428,175	1,571	3,470 12 6	1·942	2 1 0
1895	,, ...	,, ,, ,, ...	,, ,,	343,370	1,029	3,836 2 0	2·681	3 14 6
				1,010,795	3,470	9,879 1 5		
		Average Cost per ton ...	... ...	...	...	... ...	2·345	
		Average Cost per hour ...	... ...	...	...	... ...	...	2 16 11

f Includes cost of depositing 112,100 tons at sea.

Discussion.

Mr. Darley said that after six years working of the system of dredging and reclaiming by sand pumps it was both pleasing and satisfactory to him as Engineer-in-Chief for Public Works to say that the experiment had been most successful, not only in cheaply forming river channels, but also in adding valuable areas of land to those already held by the Colony. In his annual report on dredging for 1895, he had drawn attention to the fact that during the five years the sand pumps had been working, the total amount of silt raised by all the dredges amounted to 28,750,000 tons, which was more than was recorded for the thirteen previous years, while in the matter of cost, the five years average was 4·085d. per ton, against the thirteen years average of 8·219d. per ton. Several miles of stone dyking had been made at the Tweed and extensive reclamation works carried out from the silt pumped out of the channel of which the dyke was the training wall. Sand pumps were working successfully on many of the other northern rivers, and at Newcastle two were employed most advantageously, the land reclaimed having a very high commercial value. To him the most gratifying result of all the pumping work had been the entirely novel system of dealing with the silt lifted in Sydney Harbour, where there were no available reclamation sites near the wharf frontages and channels dredged. Instead of sending the silt to sea, the punts were dumped near low lying and submerged land, adjacent to valuable city and suburban properties, and with the Von Schmidt dredge, the dumped silt was pumped on to the land the property of the State, which was largely benefited both sanatorily and pecuniarily. About sixty acres of land had been so reclaimed at Leichhardt, a few acres at Callan Park, a considerable area at White Bay, and just now about fifty acres are being converted from insanitary fever plots into land which will soon command a very high price for building purposes. Mr. Portus' long experience (about thirty years in dredging work) and his knowledge of what was being done in other countries gave a special value to the paper read by him.

Mr. ALLAN said that in this class of work, it was customary, he understood, with most authorities on dredging to give the rate per ton exclusive of interest and depreciation of machinery, an item which would of course make some slight difference in the results, therefore to enable a comparison of cost to be made with other works of a similar character, it is necessary to know the basis on which the author's table was prepared. Another point of considerable importance and one upon which the author might give the results of his long experience, is the percentage of "solid stuff" passing through the pumps, with different lengths of shore pipe lines, and the power required to lift same at different depths, whilst full particulars as to the method of measurement and as to the number of cubic feet to the ton taken by the author in compiling the table accompanying the paper, would add to the usefulness of a very valuable and interesting record of centrifugal pump dredging in this Colony.

The CHAIRMAN drew attention to the dredging at the entrance of the Mersey River, referred to in his annual address, in which the cost was given at only 0·89d. per ton, representing about $\frac{3}{4}$ cubic yards of solid material passing through the pump.

Mr. HAYCROFT said, that as regards the use of leather for flexible joints, in America $1\frac{3}{4}''$ rubber is generally used for this purpose, and it was scarcely necessary to point out that this makes the best joint obtainable. With regard to the use of two spuds, the Americans use one spud, and he thought that one spud with a fixed suction end would be preferable. These were the only two points in the paper in his opinion that called for discussion.

Mr. HOUGHTON said, that although the paper contained a vast amount of information, still there was an absence of any information as to the horse power required to do the work, comparing the very long delivery pipes on the hoppers of the dredges. He would like to know from Mr. Portus, the relative difference in the power required when dredging at different depths. It was stated that the "Neptune's" indicated horse power was 300, and

that it took twenty minutes to pump 500 tons of silt into the hopper, this seemed a large proportion of power for work done.

Mr. BARRACLOUGH said he would like to ask a question as to the indicator diagrams he saw being taken, as to the power developed in the cylinders, and the point of cut-off, this would appear to have been considerably past the half stroke.

Mr. GRIMSHAW would like to draw attention to some points relative to the sand pump. The work could not be done with anything like the economy if rolling plant were used. In the latter case the cost would certainly run up to something like 1s. per cubic yard as against 1½d. to 3d. per ton. He saw three dredges during their recent inspection, all useful in their particular ways. First there was the combined sand pump, which could also be used as a grab dredge, and in addition this could be used as a floating crane, a very useful feature where small harbours were concerned. The second was the "Neptune," its chief advantage being that it had a hopper and could either carry the stuff out to sea, or pump it ashore as might be required; it could move about independent of a tug, and in fact be used as a tug. The third, the "Groper," although the most powerful, could not be applied to any other purpose than dredging, and therefore is only suitable where large areas have to be reclaimed and where a hard bottom requires to be broken up by the cutters. The very great economy gained by pumping the silt ashore as against the old method of landing it by barrows is very apparent—the landing in barrows costing at least 4½d. per ton, and when there is no lead, running up to 8d. or 1s. for a comparatively short lead. He could very well imagine that as Mr. Houghton had said, there appeared to be a great loss of power. In sucking up the silt and driving it through the pipes for so great a distance considerably more than theoretical power was required. The few men required to work one of these pumps was remarkable, as compared with the number that would be needed to shift the stuff with barrows. This class of dredge had made reclamations possible, where under the old system of doing the work, they would have been impracticable on account

of the great expense and length of time required. With regard to the number of spuds—in the Von Schmidt type—he certainly thought there would be more risk with one than with two, for it must necessitate the constant shifting of the whole plant, the first cost would no doubt be less, but the work would be done more satisfactorily with the two spuds.

Mr. PORTUS replying to Mr. Haycroft's suggestion, that rubber should be used for the joints as was done in America, stated that rubber had been tried here but had not stood the pressure as well as leather, the latter material too was cheap in the colony and was sent from Holland with the first outfit of pipes. It was intended however, to use rubber with imbedded spiral wire for suction joints shortly. The single spud system of working would not be applicable for the "Groper" type of dredge, but could be used if the suction pipe projected sufficiently past the opposite end of the dredge to enable the vessel to cut its way by arc dredging as carried out in the United States suction dredge "Ram." The Mississippi type of dredge "Beta," had many advantages and would probably be the ideal machine of the future.

In reply to Mr. Allan's question as to whether interest and depreciation were included in the cost given of dredging by sand pumps, he stated that interest on the cost of plant was not included, nor was depreciation in value; but all expenditure for repairs and for upholding the machinery in a high state of efficiency formed part of the quoted cost. The reason of interest and depreciation being excluded was that in nearly all quotations by Governments or Harbour Trusts, these two items were excluded, and for purposes of comparison this custom had been followed by the Harbours and Rivers Department of this Colony. Mr. Wheeler, M. Inst. C.E., in his work on Tidal Rivers published in 1893, writes :—"Where a sufficiently large amount of material has to be removed to warrant the purchase of plant and the employment of a regular staff, dredging in sand can be done with screw hopper suction dredges, including transport, wages, coals, repairs, and all expenses *except interest and repayment for plant*

at 1½d. per ton, with screw hopper bucket dredges working in free material at about 2½d., and with stationary bucket dredgers and steam hoppers the cost may be taken at 3½d. With hired plant and for small quantities, the price will reach as much as 1s. 6d. or even 2s. per ton." On the Tyne, Mr. Wheeler says, "the cost per ton for bucket dredging was 3·39d. per ton including repairs but not interest on outlay or depreciation."

The cost of work with ordinary sand pumps and with bucket dredges excluding interest and depreciation is (notwithstanding the eight hours system and higher rates for labour here) practically the same in Europe and New South Wales. A comparison was published in the Sydney newspapers about eighteen months since, and was included in Mr. Darley's annual report of dredging for 1894. Since that comparison was made, returns of work performed by the huge sand pump "Branckner" on the Mersey Bar have been published and the cost per ton (as quoted by Professor Warren in his annual address) has fallen to 0·89d. per ton. Nearly all the sand pump work of which the cost is given in the paper under discussion as varying from about 1½d. to 2½d. per ton, is land reclaiming work, the material having been forced through pipes for distances varying from 500′ to 2,000′, whereas the cheap Mersey Bar work consists of sand delivered directly into the vessel's hopper at two or three times the rapidity at which it would be possible to force it through pipes to the shore. When testing the hopper sand pumps "Neptune" and "Juno" at Middle Harbour, the 500 tons hopper like the "Branckner's" were filled in twenty minutes; but if the sand had to be discharged through 1,500′ of piping, an average hour's work would not exceed 200 tons. It may be stated that at the 1895 meeting of the British Association, Mr. Lyster when speaking of the work done on the Mersey Bar gave 0·81 of a penny as the cost per ton of the "Branckner" work and 1·39d. as that of the smaller sand pumps.

Mr. Allan asks for information as to how the tonnage given is arrived at, and what percentage of solid material passes through the pump with the water. It has been always the usage of the

Department, for calculation purposes, to estimate 20 cubic feet to the ton, the material being chiefly sand which averages 112lbs. per cubic foot. The number of tons pumped per day by the "Groper" is readily arrived at, as the silt is all brought alongside in punts and dumped, the hopper capacity in cubic feet of each punt being known. With the other sand pumps where original bottom is dealt with, the known duty of the pump per hour has to be relied upon and be multiplied by the number of engine hours worked at full speed. It has not been found practicable to estimate the quantity pumped by measuring the area reclaimed, because the land improved is usually so soft and spongy that the depth of sand or silt deposited cannot be reliably obtained. To ensure good work it is desirable to carry on two reclamations by working a month at each alternately, as successive layers thereby part with moisture by draining, and by being subjected to the influence of the winds and the heat of the sun. In reply to a question asked by one of the members who inspected the work of reclaiming at Rozelle Bay, it was stated that the probable pressure on the "Neptune's" delivery pipe near the pump was at that time about 6lbs. per square inch. This was tested afterwards by fiixng a pressure gauge at the pump, which showed 9 lbs., while at 300′ away from the vessel a pressure of 2 lbs. was indicated, the total length of pipe at the time was 800′. Respecting Mr. Allan's question as to power, the indicated horse power of the "Groper's" engines as taken on the 4th August last was 244 horse power, when dredging to a depth of 18′, and delivering silt a distance of 1,250′ through a 20″ pipe. The material dealt with was lifted to a height of 16′ above water level, and the quantity sent on shore was 400 tons per hour. The velocity of the discharge was $11\frac{1}{2}$′ per second. The percentage of solid material in the mixture dredged and delivered varies from 20 to 40 per cent. The great Mississippi dredge "Beta's" percentage is given as from about 20 to 34, but the distance is only 1,040′. The following records would be useful in connection with the paper :—

Dredge "Neptune," 18/11/96.—Sand Pump Tests.

Boiler pressure 75lbs.□	Pressure at pump, pure water	7lbs.□	
Vac. engines 24″	,, 300′ ,,	2lbs.□	
Revs. of engines 134	Pressure at pump, full bore silt	9lbs.□	
Diam. of spinner 6′ 6¾″	,, 300′ ,,	3½lbs.□	
Cylinders 20″ and 36″ stroke 2′	Vac. on pump, pure water	6″	
	,, ,, full bore silt	10″	

Material dredged sand and mud. Length of pipe line 800′.

Pressure on "Groper's" Discharge Pipes.

15lbs. at ship's side
10lbs. 300′ out
} with clear water 130 revolutions per minute.

20lbs. at ship's side
13lbs. 300′ out
} with sand and shell 130 revolutions per min.

Distance to end of pipes 2,500′ ; 5′ rise of tide.

Boiler pressure 100 lbs. per square inch.

Cylinders 20″ and 36″ stroke 2′.

Mr. Houghton's question as to power was practically answered by the information just given, the work done and power expended when dredging and discharging at a distance of 1,250′ being quoted. In practice it was found that the difference in power was inconsiderable as between dredging by pump at 10′ or 20′ depths. Height and distance after leaving the pump were the chief factors to reckon with. Mr. Houghton would see by again referring to the paper read, that 300 h. p. was not quoted as the power developed when the "Neptune's" 500 tons hopper was filled in nineteen minutes. Cards were not taken at that time, the power was considerably less than the 300 obtained under other conditions.

Respecting the point of cut off in the sand pump compound engines referred to by Mr. Barraclough, it was between ½ and ⅝ of the stroke, and although the triple expansion engines with 160lb of steam designed by the Department were more economical than the compound ones, which were purchased, there was little to complain about in the latter as a pair of them having cylinders 12″ and 24″ developed with 120lbs. of steam, and with moderate consumption of coal over 200 horse power.

THE PRESENT POSITION OF THE THEORY OF THE STEAM ENGINE.

By S. H. BARRACLOUGH, B.E., M.M.E.

[*Abstract of paper read before the Engineering Section of the Royal Society of N. S. Wales, November 18, 1896.*]

THE purely thermodynamic theory of the steam engine fails to take account of the large amount of heat which is stored in the metal walls of the cylinder when the steam is admitted, and the greater part of which is restored to the steam at the exhaust, thus passing through the cylinder without producing any useful effect, and also of several other minor losses of heat due to external conduction and radiation. These wastes are gradually being investigated, and their mode of variation determined, thus giving rise to what has been termed "the experimental theory of the steam engine."

In dealing with any question of steam engineering there are three aspects to be considered, which we may rather roughly but satisfactorily term—(1) the financial, (2) the mechanical, (3) the scientific.

1. The financial side of the question is of course intimately connected with the scientific and the mechanical, and is the controlling factor in designing a steam power plant. The important question is not "What engine will use the least amount of steam per H.P. hour"? nor "What boiler will evaporate the greatest amount of water per pound of coal"? but it is "What complete arrangement of the plant will involve the least annual expenditure of money"?

No general principles seem possible with regard to choice of type of boiler and engine for maximum commercial efficiency. The particular circumstances of any given case have such a predominating influence, and vary so widely that it would be impos-

sible to classify them, and so recourse must be had to a system of trial and error in which an examination is made of two or three types of boiler and engine, which experience indicates to be the most suitable. The adoption of such a system is greatly assisted by carefully prepared tables giving the cost of steam power per H.P. per annum under a great variety of typical sets of working conditions. One of the most elaborate and practically useful series of such tables has been prepared by Dr. Chas. E. Emery of New York.[1] Such an investigation often shows that the saving in fuel resulting from the use of a more than usually efficient, but expensive engine, is not sufficient to warrant the increase in first cost. Many similar but less complete investigations of the cost of steam power have been published.[2]

Supposing however the type of boiler and engine to have been selected, the proportions and size of the engine necessary for maximum financial efficiency can be determined with a very fair approximation to accuracy. Perhaps the most successful attempt at accomplishing this is due to Prof. Thurston,[3] who (following up a method suggested by Rankine[4]) has elaborated a system by which can be determined the ratio of expansion involving the least annual expenditure. The assumption is made that the ratio of expansion is an independent variable upon which the various losses and costs depend, and from the best ratio so determined the proper size of engine can be at once computed.

2. It may seem somewhat arbitrary to draw a line between the mechanical and the scientific side of engine design, but for purposes of convenience such a distinction will be made by considering the mechanical side to embrace all that goes on after the conditions of working such as the steam pressure, ratio of expansion and speed have been determined together with the size and

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1 "The cost of steam power produced with engines of different types under practical conditions."—Sib. Journ. Eng., March, 1893.

2 *e.g.*, Unwin's "Development and Transmission of Power," Chap. III.

3 Thurston—"Manual of Steam Engine," Part I., Chap. VII.; also Proc. Inst. Naval Arch. 1895.

4 Ship Building, appendix.

proportions of the cylinder. It has to be remembered that steam engine design is an art as well as a science, and that, as is usually the case, the art is always in advance of the science.

3. A century's progress in the design of the steam engine, with its remarkable accumulation of knowledge, experience, and skill, has only produced this result, that when we put 100 lbs. of coal into the boiler, from about 90 of them we obtain no return in the way of useful work. Poor though this result may appear, it is really a remarkably good one, when we remember that at the beginning of the century the engines of James Watt were probably not giving the equivalent in work of more than 1 lb. of coal for every 100 burnt in the primitive boilers of those days. The following distribution of heat for every 100 heat units contained in the steam supplied to the cylinder may be taken as representing an average case of an unjacketed simple engine:—

Waste by external conduction and radiation	5·5	per cent.
Waste by internal conduction (cylinder condensation)	35	„
Waste—thermodynamic	48	„
Waste by friction	1·5	„
Useful work	10	„

The wastes, it will be seen, group themselves under three heads:

A. The thermodynamic waste.

B. The mechanical waste.

C. The thermal waste.

A. With regard to the first of these wastes,—the thermodynamic—there is no difficulty whatever in accurately computing its amount.

If T_1 be the absolute temperature at which heat is supplied to a heat engine, and T_2 that at which it is rejected, then the maximum efficiency which it is possible to obtain is given by the equation

$$E = \frac{T_1 - T_2}{T_1}$$

which shews the greatest possible fraction of a given quantity of

heat, H, supplied to any engine that can theoretically be used. Hence it is perhaps rather a misnomer to talk of a thermodynamic waste. It might possibly be more correctly termed the thermodynamic disability of the heat engine. Supposing, for instance, steam were introduced into the cylinder at a pressure of 90 lbs., corresponding to a temperature of 320° F., and that it was rejected to the condenser at, say 100° F., then the maximum possible efficiency would be given by

$$\frac{320 - 100}{320 + 461} = \frac{220}{781} = 28\%$$

or, in other words, out of 100 heat units passing through the cylinder, only 28 could possibly be turned into available work.

The ordinary cycles adopted in steam engine cylinders are not completely reversible, as it is impossible to secure the adiabatic compression necessary to bring the working fluid back to the initial pressure before the succeeding cycle begins, and on this account the possible thermodynamic efficiency of the actual engine is lower than that indicated by the above equation. This fact has given rise to a controversy[1] as to the correct standard cycle with which to compare the steam cycle in any particular engine. The question is one to which there seems no finality, but in the author's opinion few satisfactory reasons have been advanced against the adoption of the original Carnot cycle as a standard, rather than one of the more recent cycles that have been proposed. It is a cycle of maximum efficiency and of definite value, towards which all engines should be made to approximate, even though they might never actually attain to it.

B. The mechanical or frictional wastes depend almost entirely on the structural form of the engine, and are capable of easy and approximate computation. In some engines of exceptionally good mechanical design and construction the frictional waste is reduced to 5% of the total power developed in the cylinder. For good general practice, however, a more usual figure is 10%. As first

[1] Proc. Inst. C.E., Vol. CXXV., p. 182.

stated by De Pambour, the friction of an engine consists of two parts—its friction when running unloaded, and in addition, a further amount caused by the engine taking up its load, and so increasing the pressure on the running parts. This is undoubtedly correct, but practically it is often found, more especially in the case of non-condensing engines, that this additional frictional loss is not important or even observable.[1] The frictional waste is generally only a small percentage of the total waste in an engine, and as its amount can be very approximately determined, the total error introduced into the designer's computations is unimportant and calls for no further treatment.

C. There thus remains only the thermal loss to deal with, and this most important form of waste due to conduction and radiation of heat within and from the cylinder, is the point towards which nearly all recent investigations have been directed. One portion of the radiation loss is external and takes place through the heated cylinder heads and barrel (to an extent dependent on the quality of the lagging) and also from the piston and valve rods alternately heated and cooled as they enter and leave the cylinder. This portion of the loss is small in amount (as may be seen from the foregoing table) and regular in action, and consequently in any given case may be readily computed from observations taken under similar conditions in actual practice. The second and by far the most important portion of this waste due to conduction and radiation is internal, and constitutes the much discussed "cylinder condensation." Its importance is due to the fact that it is large in amount and that the causes affecting it are not thoroughly understood, no formula or principle either empirical or rational having yet been produced which satisfactorily expresses it.

The general reason for the occurrence of cylinder condensation is to be found in the fact that the cylinder is not made of non-conducting material, and that the interior walls of the cylinder are not at the same temperature as the steam in contact with them.

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[1] "On the distribution of internal friction of engines,"—Trans. Am. Soc. Eng., Vol. x.

As the steam enters the cylinder and strikes against the walls which have been chilled by contact with the previous exhaust steam, a portion of it, often reaching 30 or 40 and sometimes 50% is condensed and deposited probably in the form of a fine dew, this condensation goes on to a greater or less extent during the whole period of admission, after the point of cut-off has been passed there is a co-existing condensation and re-evaporation going on, the former predominating as a rule only during the very early stages of the expansion and the latter towards the end of the stroke. After the opening of the exhaust a sudden and possibly total re-evaporation takes place. During the final compression stage of the cycle preceding the admission of the steam, there may also be a twofold action, compressing the steam would tend to dry it and raise its temperature, but at the same time owing to the cylinder walls being at a lower temperature than the steam, heat would flow from the steam to the metal with a corresponding condensation of the steam. The best method of illustrating the loss by cylinder condensation is probably the now usual one of comparing the expansion line of an indicator card with the corresponding saturation curve, and so from the magnitudes of the volumes as indicated by the curves at any given pressure, deducing the "quality curve" of the steam,

All the variable conditions of working will affect the amount of the loss by condensation, and a rough estimate may be formed of the effect which a change in one or more of these conditions will produce in any particular case. The conditions which are usually assumed to be most potent in affecting the amount of the loss by cylinder condensation are—

(*a*) Revolutions per unit time.
(*b*) Steam pressures, and corresponding temperature ranges.
(*c*) Ratio of expansion.
(*d*) Proportions and size of cylinder.
(*e*) Condition of the surface exposed to the incoming steam.
(*f*) Clearance volume.
(*g*) Thermodynamic condensation, and indirect effect of same.

(*h*) Quality of steam at admission.

(*j*) Several special expedients arbitrarily applied, *e.g.*, steam jacketing, superheating, introduction of air into the cylinder, and so forth.

(*a*) Increasing the speed of an engine lessens in a very marked degree the condensation waste, but authorities differ widely as to the precise mode of variation. In several proposed formulæ, based on experimental results, the loss is stated as varying inversely as the square root[1] of the number of revolutions per minute, in others inversely as the first power[2] of the number of revolutions, while yet in at least one other as the $\frac{2}{3}$ power.[3] It should be remembered that although increasing the speed diminishes the loss by initial condensation, it increases the frictional loss and may be the cause of incurring other expenses to an extent that will discount very considerably the primary gain.

(*b*) Variations in the admission steam pressure have an important influence on the magnitude of the thermal loss, whereas the effect of altering the back pressure appears to be almost insensible. With any particular engine the total number of heat units given up to the cylinder walls per revolution increases with the pressure[4] and may be expressed by an equation of the form

$$H = K P + C$$

where H is the heat loss, P the initial pressure, and K and C are constants depending on the other working conditions. The weight of steam condensed does not however increase as fast as the total weight of steam used, so that the percentage condensation diminishes with increase of initial pressure This fact is of great importance in that it distinctly contravenes the assumption very commonly made that percentage condensation is directly proportional to the temperature range from admission to exhaust, which is equivalent, if the back pressure be kept constant, to assuming

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[1] Cotterill—"The Steam Engine," p. 339. Thurston—"Manual of the Steam Engine," p. 510.

[2] Journ. Frank. Inst., Feb. 1886. [3] Industries, Oct. 1890.

[4] Proc. Inst. C.E., Vol. cxx., p. 327.

that the percentage condensation increases with the initial pressure. Indeed, an examination of the published results of various series of tests goes to show that there is no evidence of the loss by cylinder condensation being in any way a function of the temperature range either from admission to exhaust, or from cut off to release. The temperature range of the cylinder walls, which has an important effect on the amount of the heat loss, is probably less than that of the steam, and the temperature cycle through which the metal near the interior surface of the cylinder passes must be of a most complex character. The question of this cycle and of the conditions affecting it has been ably investigated by Kirsch,[1] and has been the subject of some interesting experiments by Mr. Bryan Donkin.[2] The plan of these experiments has since been considerably improved upon by the adoption of a thermo-electric method of measuring the temperatures.[3] The various experiments however combine to make it evident, as would be expected from theoretical considerations, that the thickness of metal which passes through a regular temperature cycle is very small, and varies with change of working conditions, more especially with that of speed. An accurate knowledge of the temperature cycle of the iron would be of great assistance in determining the mode of variation of cylinder condensation and there seems every prospect of this being gained by means of the temperature "indicator diagrams" lately obtained by Mr. E. Adams at Sibley College.[4] These diagrams show the complete temperature cycle through which any particular part of the metal passes during one revolution. By taking such diagrams at different points in the cylinder heads and barrel and at different distances from the interior surface of the cylinder, an accurate knowledge of the temperature cycle of the metal may be expected to be obtained.

(c) The ratio of expansion, although not itself a physical quantity, yet is directly connected with several physical quantities

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[1] Die Bewegung der Wärme in den cylinder Wandungen, Leipzig 1886.

[2] Proc. Inst. C.E., Vol. cxv. [3] Sib. Journ. Eng., June 1895.

[4] For an account of the method adopted see Cassier's Magazine 1894.

such as the area exposed to admission steam, the range of temperature during expansion, the relative times of duration of admission and expansion, and so forth. Altering the value of the ratio of expansion is however found to affect the amount of cylinder condensation in a fairly regular manner, and consequently the waste may be satisfactorily expressed as a function of the ratio of expansion. What this function is has not yet been satisfactorily determined; it can only be stated in general terms that, within the limits of the ratios of expansion usually adopted, the waste increases as the ratio increases.

(*d*) Proportions and size of cylinder. These two conditions must necessarily have a very important influence on the percentage of steam in a cylinder which is condensed, but the exact relationship has not been determined. The difficulty of making series of experiments upon many engines of different proportions and sizes under otherwise exactly similar conditions is very great. It is known of course in a general way, that the heat loss is less proportionally in an engine of large power than in a small one, and that the less clearance surface per pound of steam the better.

(*e*) Condition of surface exposed to the incoming steam. With regard to the effect which this condition has on the amount of the loss by initial condensation, the experimental evidence is not very large, and is on the whole opposed to what would be naturally anticipated. It has usually been assumed that certain conditions of the clearance surface would exert a marked influence in modifying the amount of the heat loss, that, for instance, when the clearance surface is coated with grease, its effect in causing condensation is small,[1] but tests made of engines in which the piston surfaces and cylinder heads were coated with lead,[2] with porcelain,[3] and with other substances of different heat conducting powers than those of iron, appear to show practically no difference in the

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[1] Cotterill—"The Steam Engine," p. 339.

[2] Proc. Inst. M. E., 1887, p. 524.

[3] Thurston—"Manual of the Steam Engine," p. 495, note.

amount of steam consumed. On the other hand, Mr. Bryan Donkin in the paper already quoted, states that a coating of varnish distinctly lessens the condensation waste, and although his experiments were carried out on a specially constructed apparatus and not on an engine cylinder, the results are comparable with those obtained from an engine test. It is thus evident that the precise effect of the condition of the clearance surface is at present not known.

(*f*) Clearance Volume. It is to be regretted that no systematic and extensive series of experiments on the relationship between clearance volume and cylinder condensation, have as yet, been reported. That the economy of an engine is greatly affected by the amount of clearance volume is generally admitted, but the precise relationship is undetermined.

(*g*) Thermo-dynamic condensation. Rankine and Clausins independently demonstrated about 1850 that when steam expands adiabatically a portion of it is liquefied. This liquefaction is not very large, except in the case of high pressures and large ratios of expansion, and its amount can be computed in a perfectly straightforward manner. It is not of course to be considered as a waste in the ordinary sense, since it is the result of the useful work done by the expanding steam against the resistance of the piston, but it has however sometimes been regarded as exerting a very important indirect effect in that the presence of the water mist caused by the thermodynamic liquefaction would produce increased condensation of the entering steam. Experiment has however never shown any essential connection between the two.

(*h*) The quality of the steam, or the percentage of dry steam in the entering mixture of steam and water has not been the subject of very much experimental investigation, as regards its influence on the amount of initial condensation. An excess of entrained water in the steam is of course practically objectionable, but, at any rate in the case of the particular types[1] of engine so

[1] "Experimental determination of the effect of water in steam on the economy of the steam engine."—Trans. Am. Soc. Mech. Engrs., Vol. xv.

far experimented on, it has been found that the consumption of dry steam per indicated horse power hour is independent of the quality of the entering steam.

(*j*) Such conditions of working as steam jacketing, superheating and compounding do not come within the scope of this paper. Their adoption in any particular steam engine of course completely alters the mode of variation of the heat losses.

The introduction of air into the cylinder has been found[1] to have a beneficial influence in lessening the initial condensation, but owing to practical difficulties the plan has never been widely adopted.

In attempting to determine the principles governing "cylinder condensation" the usual plan has been to select one particular working condition, (such as speed or initial pressure) and, keeping all other working conditions constant, to make a series of tests with different values of this one condition. Then the cylinder condensation for each test is computed, and the quantities thus obtained are co-ordinated with the respective values of the working condition under investigation. From the curve so determined the form of the function connecting the two is derived. This process repeated for all the other working conditions would similarly fix their corresponding functions. Messrs. Gately and Kletsch, under the direction of Prof. Thurston, were the first to take up this systematic experimental study of the cylinder losses,[2] and they have been followed by a very large number of others. The actual result of so much investigation is not as great as it might be had more attention been paid to the systematic planning of each series of tests. To completely determine the mode of variation of cylinder condensation with all the different working conditions a series of tests should comply with the following requirements :—

1. The greatest possible range of variation of each condition should be obtained.

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1 London Engineering 1873. 2 Journ. Frank. Inst., October 1885.

2. The number of tests made while varying only one working condition, should be as great as possible, rarely less than five being of any use, and more being desirable.

3. Not only each working condition, but also each set of working conditions should be systematically varied.

None of the published series of engine tests completely comply with these requirements, more especially with the third of them. Even the elaborate series of tests made by Willans are very disappointing when examined in this respect, the method of varying the sets of working conditions being irregular and unsystematic.

Neglect of these requirements has led to many altogether unwarranted deductions being drawn from the results of different engine tests, for if three or four points only are available to determine the position of a curve, and more particularly if these points are close together, almost any variety of curve can be made to fairly represent them, and consequently all kinds of cylinder condensation formulæ can be produced, which although they may approximately represent the results obtained from any particular set of tests are yet quite erroneous as statements of general principles. That such has been the state of things is evidenced by the remarkably varied character of the already proposed condensation formulæ some of the more familiar examples of which are quoted herewith.[1] The list is not at all exhaustive, indeed under the circumstances there is no object in making it so.

1. $$y = \frac{C \log_e r}{d N^{\frac{1}{2}}}$$

2. $$W = C A (T_1 - T_2) t$$

[1] These formulæ are so generally known (with possibly the exception of the last) that it is not necessary to give any detailed description of them. It should be noted however, that in some cases the formulæ are not strictly comparable; for instance in No. 1, "y" is the ratio of water to *dry* stream, while in No. 3, "x" is the ratio of water to *total* steam. The following are the references for the various formulæ:—No. 1, Cotterill—"The Steam Engine," p. 339; No. 2, Thurston—"Manual of the Steam Engine," p 508; No. 3, *Ibid.*, p. 517; No. 4, Industries, Oct. 1890; No. 5. Proc. Inst. Mech. Engrs., 1889; No. 6, Sib. Journ. Eng., June 1896.

$$3. \qquad x = b \frac{(T_1 - T_2)}{d\ N^{\frac{1}{2}}} r^{\frac{1}{2}}$$

$$4. \qquad Q = C \frac{(T_1 - T_2)\ S}{N^{\frac{1}{3}}}$$

$$5. \quad C\ W = \rho_1\ K \frac{S}{N^{\frac{1}{3}}} \frac{T_1}{T_m}$$

$$6. \qquad y = \frac{C\ (r-1)^m}{d\ \ N^k}$$

The want of harmony in these various formulæ is astonishing. Cylinder condensation is made proportional, as regards speed to $\frac{1}{N}$, $\frac{1}{N^{\frac{1}{2}}}$, $\frac{1}{N^{\frac{2}{3}}}$ and $\frac{1}{N^k}$, as regards ratio of expansion to $\log_e r$, $r^{\frac{1}{2}}$ and $(r-1)^m$ and similarly as regards the other conditions. Such disagreement would be brought about by the neglect of the third of the above mentioned requirements, even if the first two were satisfactorily complied with. It by no means follows as has been assumed by the authors of most of these formulæ that the relationship between initial condensation and any one working condition, say the speed, is even approximately the same when, say, the boiler pressure is at 80 lbs. per square inch as when it is at 160 lbs. per square inch. This makes it necessary in order to determine the relationship between cylinder condensation and one particular working condition, not merely to carry out one series of tests, but to carry out such a series again and again, each time altering the value of one of the other working conditions, in order to determine the effect which such a change would have on the form of the function connecting cylinder condensation and the first mentioned condition. If we suppose r, N and P to be the ratio of expansion, speed and initial pressure respectively, then it is not true as is often assumed that

$$L = f(r)\, f'(N)\, f''(P)$$

where L is the cylinder loss, and f, f' and f'' are constant functions of their respective conditions, but that

$$L = F(r, N, P)$$

where F is a function involving all the variable working conditions.

The amount of labour necessary for a complete determination of this function is very considerable, as may be seen by considering a particular case. Let it be supposed that it is desired to make an investigation of the effect which changes of pressure, speed and ratio of expansion have upon the heat loss by initial condensation in some particular engine, and that five tests are considered sufficient for each series. The following table may then be taken as giving the particular values chosen.

Pressure lbs. abs.	Speed R.P.M.	Ratio of Expansion.
120	200	10
100	160	8
80	120	6
60	80	4
40	40	2

It is at once evident that the number of engine tests necessary to carry out this investigation completely, is 125, and if a fourth working condition were to be introduced into the problem the number would be increased five times. As the carrying out and working up of an engine test is a matter involving a considerable expenditure of both time and labour, we have doubtless in the large number of such tests necessary, an explanation of the unsatisfactory nature of the experimental investigations of the heat losses hitherto attempted. In conjunction with Mr. L. S. Marks, the writer initiated such a series of tests,[1] as is here suggested, on a Corliss engine at Sibley College, U.S.A. The time at their disposal only allowed of the complete investigation of the effect of two conditions—speed and pressure, but the result of the investigation was to support the above opinion entirely. The heat loss was found to vary as the reciprocal of some power of N, the number of revolutions per minute, but the index of this power depended on the pressure, so that the formula for "cylinder condensation" when both speed and pressure were subject to variation was of the general form

$$L = \frac{K}{N^{f(P)}}$$

[1] Proc. Inst. C.E., Vol. cxx., p. 323.

The work on this engine has since been carried on by others, and it is hoped that in the near future sufficient experimental results will be available for a complete investigation of the mode of variation of the thermal losses in this particular type of engine. Meanwhile from the results already obtained, Mr. A. L. Rice has deduced the formula for cylinder condensation already quoted

$$y = \frac{C\,(r-1)^m}{d \quad N^k}$$

where "C," "m" and "k" are functions of the pressure.

Sufficient information is not yet available to allow of a thorough criticism of this formula, but in the account published by its author, the statement is made that it has been found to closely accord with the results of tests on a large variety of engines working under widely differing conditions, and undoubtedly the principle adopted in the construction of the formula, of using variable functions of the different working conditions, is the correct one.

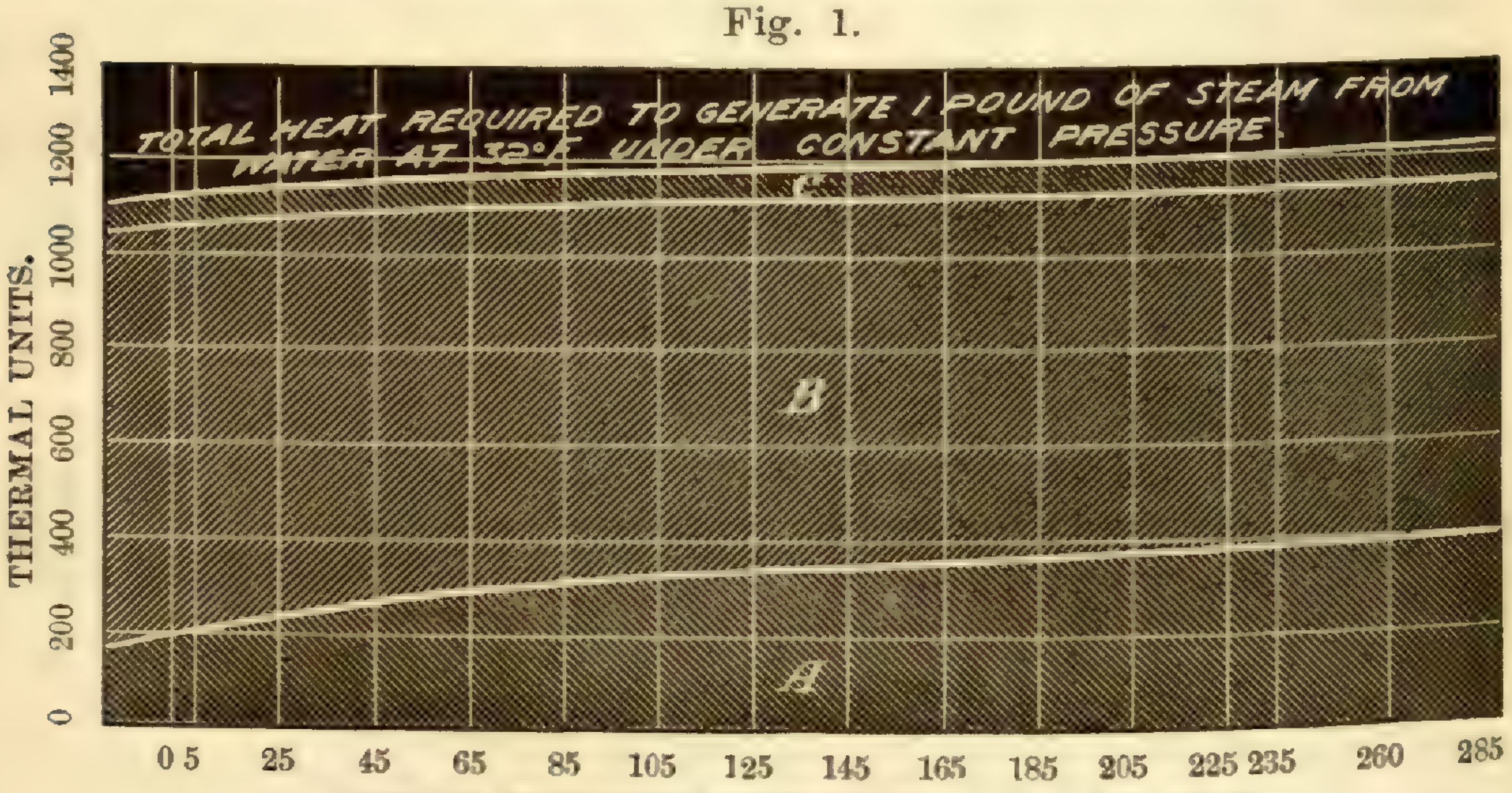
Probably sufficient has now been said to show that a considerable amount of experimental work will still be necessary before the conditions affecting the heat wastes in a cylinder are thoroughly investigated. When this investigation is complete the material will be at hand for an exhaustive theory of the steam engine.

Discussion.

Mr. Houghton said that Mr. Barraclough's paper, although a most valuable contribution, was not one which could be readily discussed. The statement made in the paper that only about 10 per cent of the heat supplied to the cylinder could be turned into useful work was generally true—in some engines 15 per cent, is utilised—but the reason of this arose from no fault of the engine but of the medium used to convey the heat of the coal to the cylinder. In converting water into steam, that is into gas, a large amount of heat is expended in overcoming the internal resistance to evaporation and this is responsible for the loss as it is impossible

at present to fully use this heat. Fig. 1 shews the total amount

Fig. 1.



A—Heat required to raise 1lb. of water from 32° Fah. to boiling point.

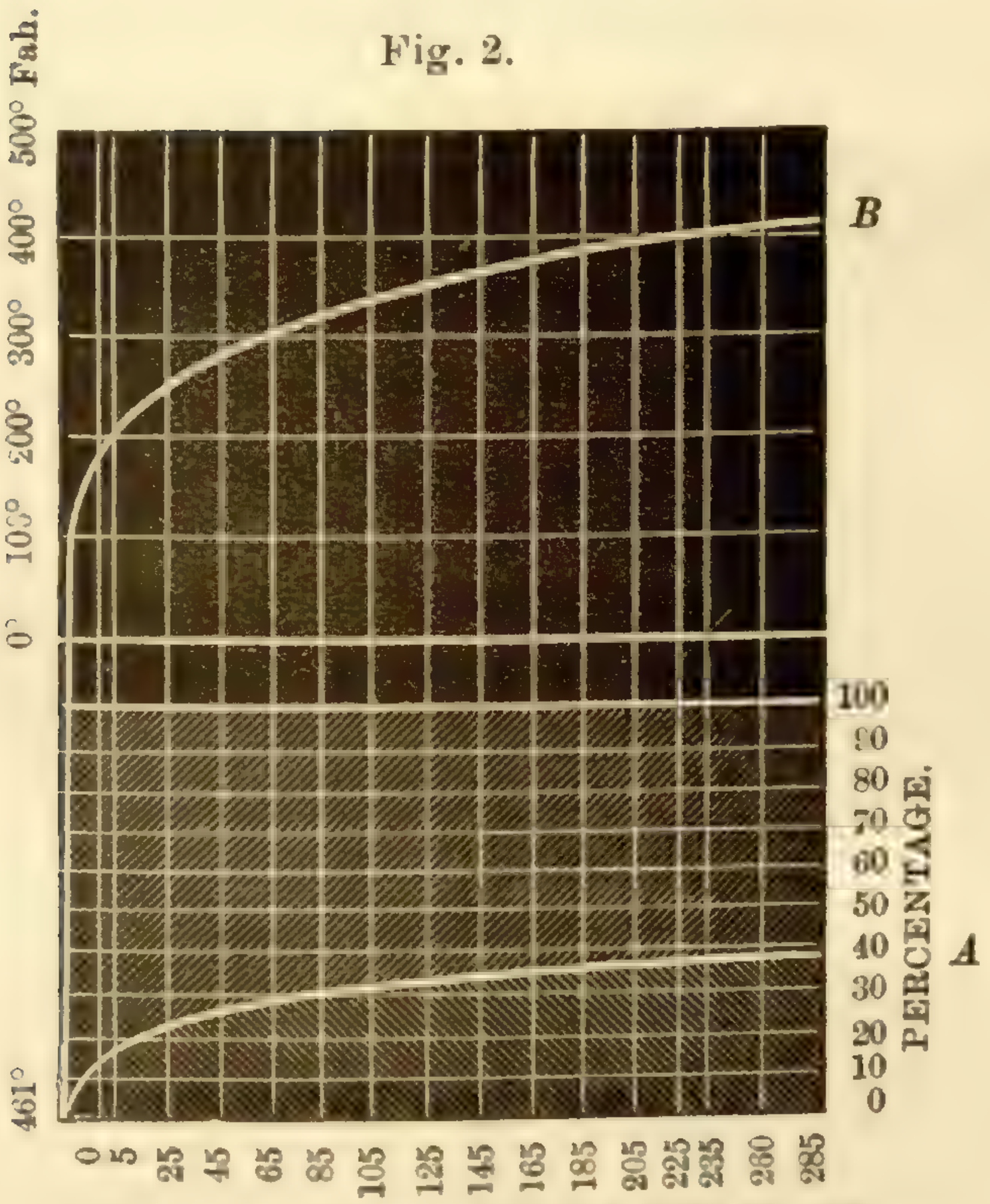
B—Heat absorbed per pound of steam in overcoming the internal resistance to vaporisation.

C—Heat disappearing per pound of steam in overcoming the external resistance to expansion.

of heat measuring from 32° Fah. contained in a pound of steam at varying pressures, this is made up of three portions, first the heat required to raise the water from 32° to the temperature of the steam A, second the heat required to overcome the internal resistance to vaporation B, that is the heat required to convert the water into a gas, and third the heat expended in overcoming the external resistance to expansion C, A and C increase with the pressure at a greater rate than the total heat increases, so that it will be seen at a glance that the higher the pressure the greater the amount of total heat that is available for useful work, as all the heat due to the resistance to internal evaporation, corresponding to the pressure at which the steam is exhausted from the cylinder, goes to waste.

Fig. 2 shews graphically the maximum possible efficiency in per centages that is obtainable when using steam at any pressure up to 285lbs., the top curve shews the corresponding temperature in Fah. degrees, and the second one shews the percentage of heat

Fig. 2.



A—Percentage of heat available for useful work.

B—Temperature of steam.

that can possibly be utilised, supposing the engine considered as a heat engine to be a perfect engine, the temperature of the condenser being taken as 100° Fah.

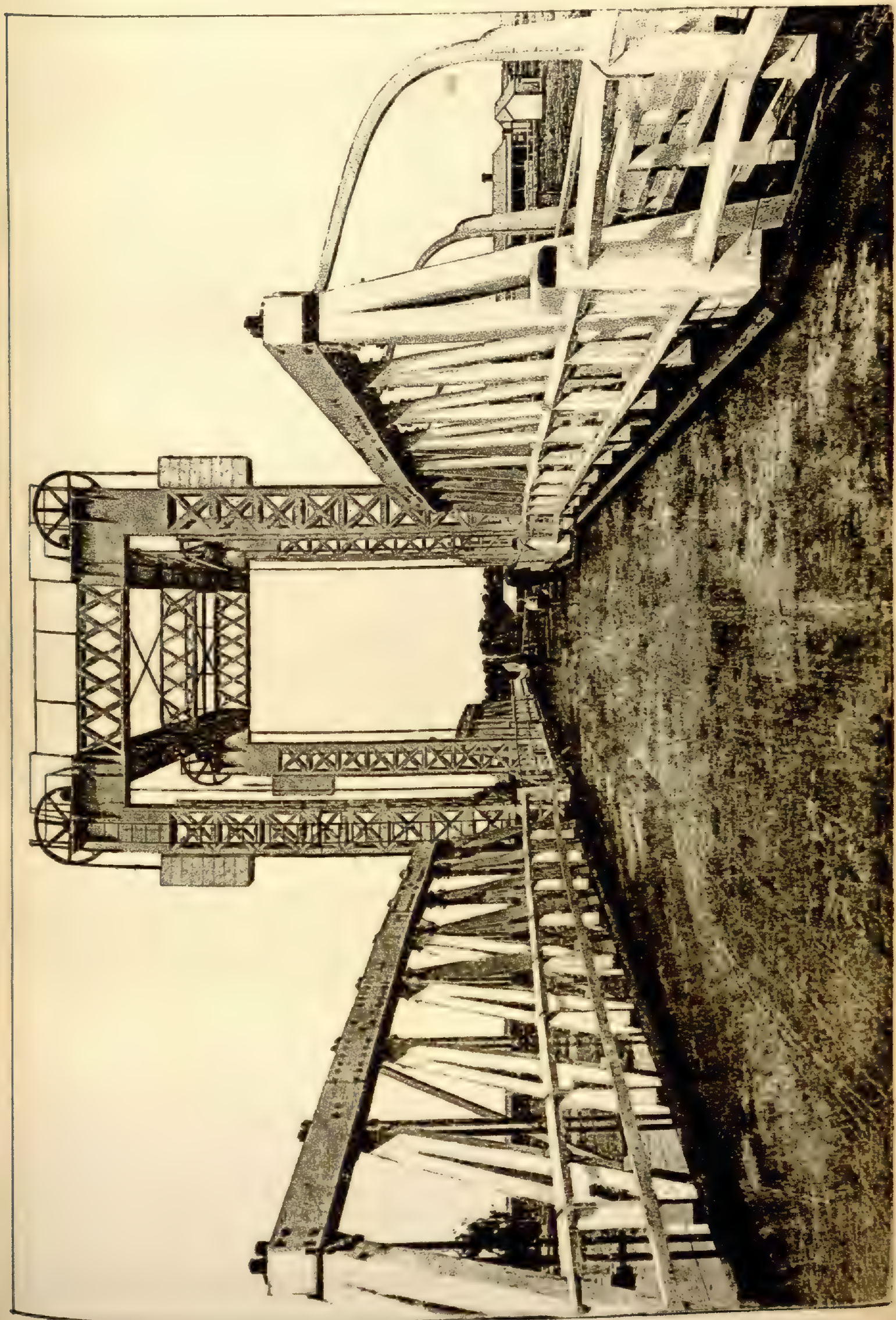
It will be noticed that with steam of 285 lbs. pressure, and assuming that we are dealing with a perfect heat engine, it is impossible to turn more than 35 per cent of the heat supplied into useful work. There is much to be done in the future to increase the economy of the steam engine, and researches like those described by the author are the only means to attain that end.

Mr. BARRACLOUGH in reply said he was greatly obliged to Mr. Houghton for the diagrams he had prepared. He however, could not agree with him that there was very little debateable matter in the paper. One object which he had in view in writing the paper was to show the marked divergence in the opinions of those who are in a position to write with authority on the subject. The

existence of such differences of opinion was sufficient proof that the field for discussion was a wide one. In particular, he would have liked to hear some discussion as to the proper method for the construction of a formula to represent the heat loss due to initial condensation.

PLATE I

PLATE 2



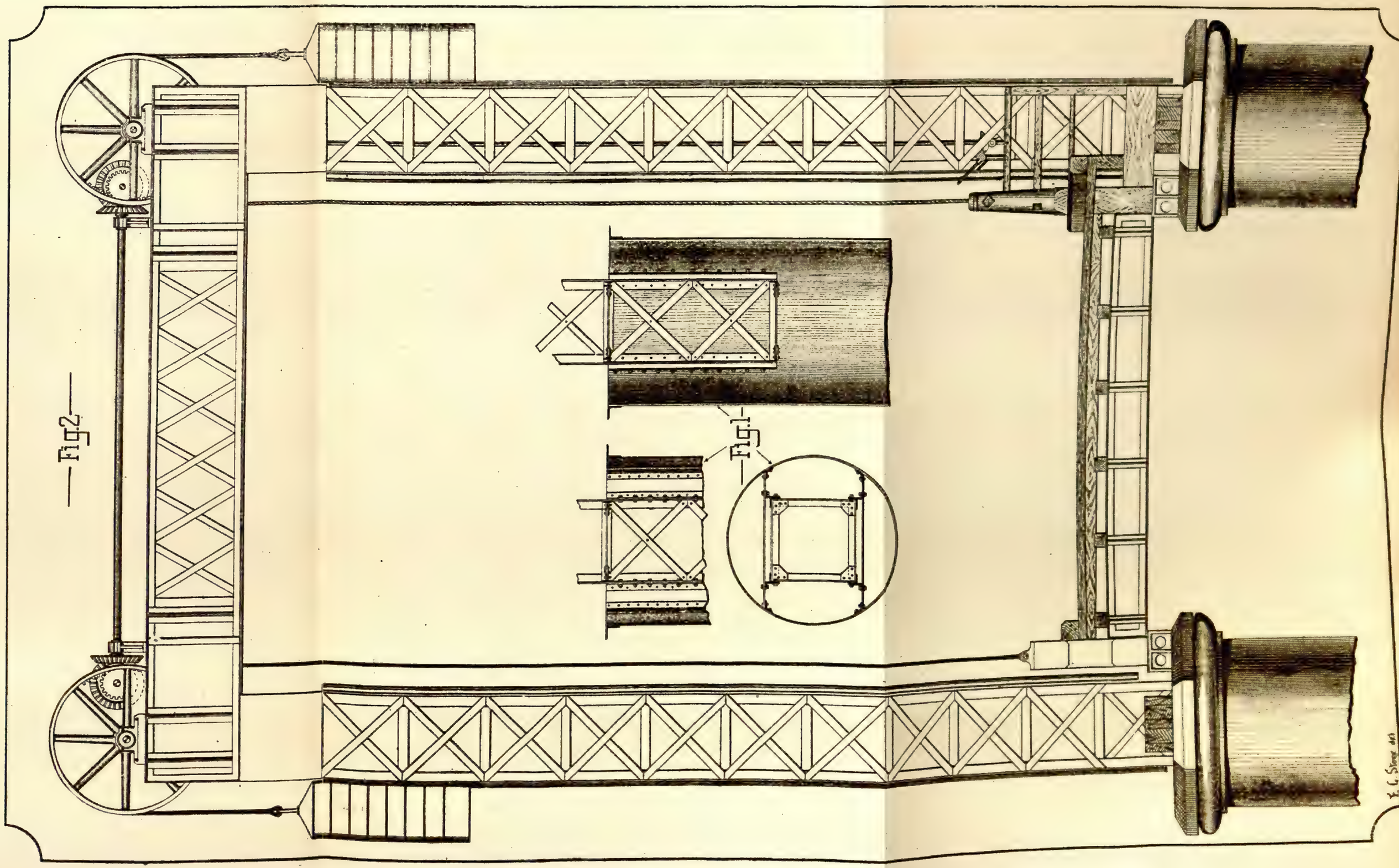
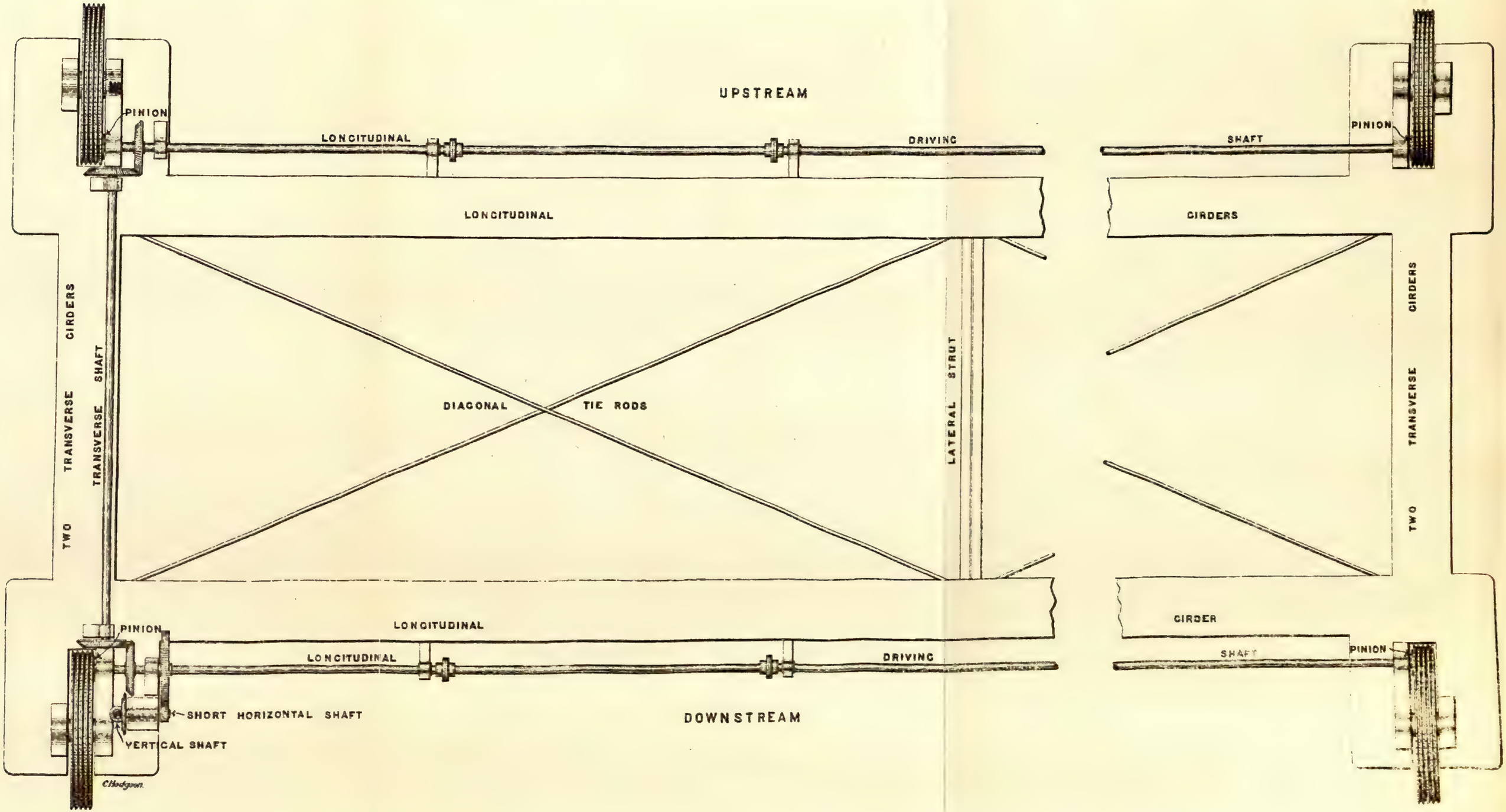


Fig.2
Fig.1

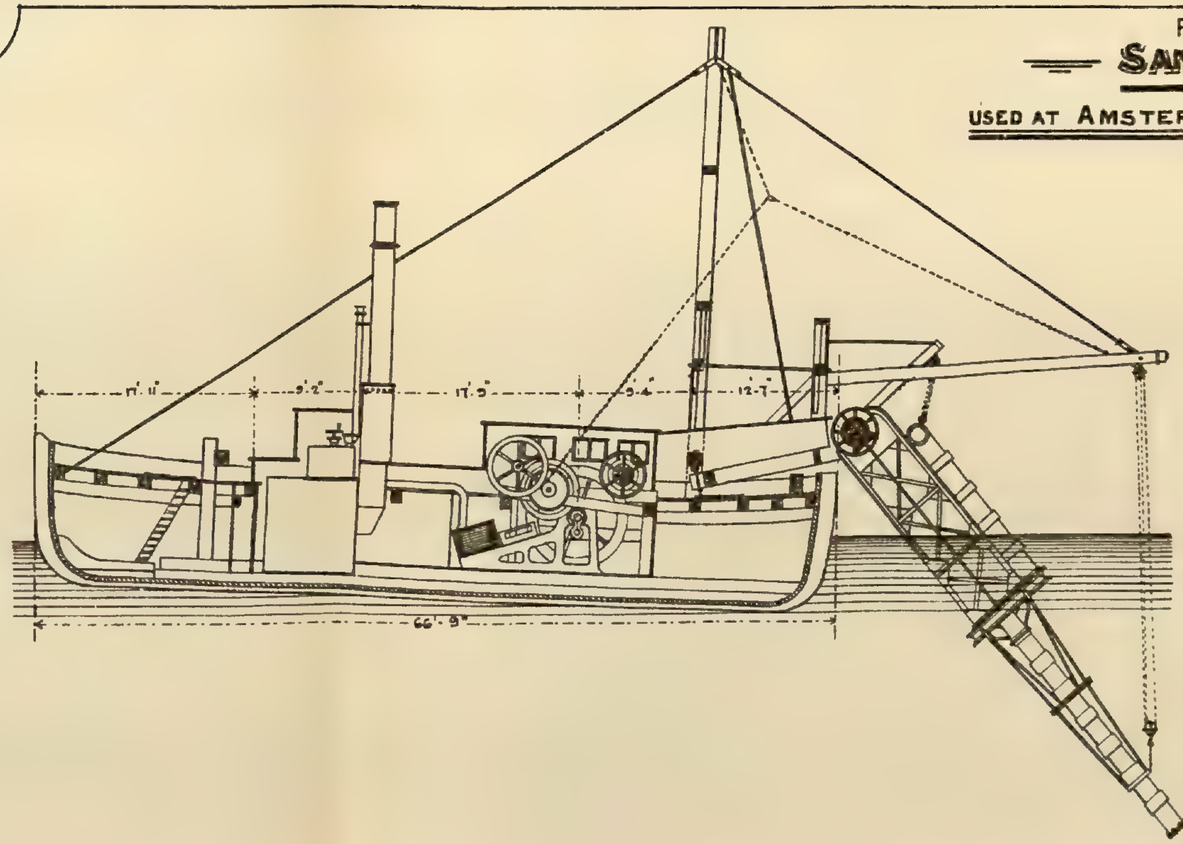

UPSTREAM
PINION
LONGITUDINAL
DRIVING
LONGITUDINAL
CIRDERS
TWO TRANSVERSE CIRDERS
TRANSVERSE SHAFT
DIAGONAL TIE RODS
LATERAL STRUT
PINION
SHAFT
CIRDERS
TWO TRANSVERSE
PINION
LONGITUDINAL
LONGITUDINAL
DRIVING
SHORT HORIZONTAL SHAFT
VERTICAL SHAFT
DOWNSTREAM
CIRDER
SHAFT
PINION
C. Hodgson

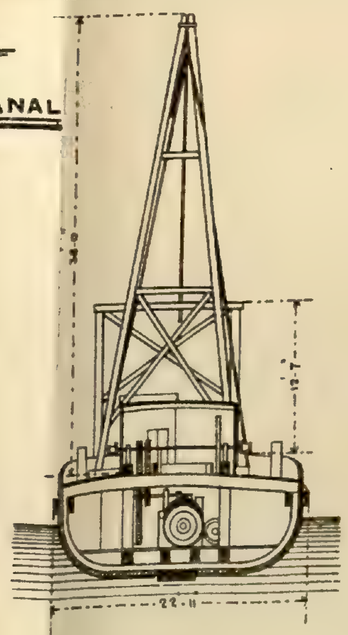
FIRST

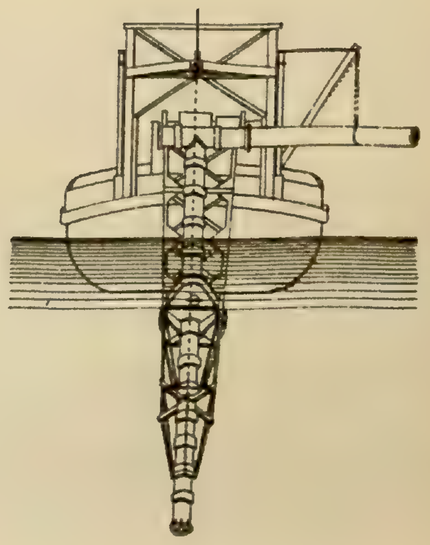
SAND PUMP

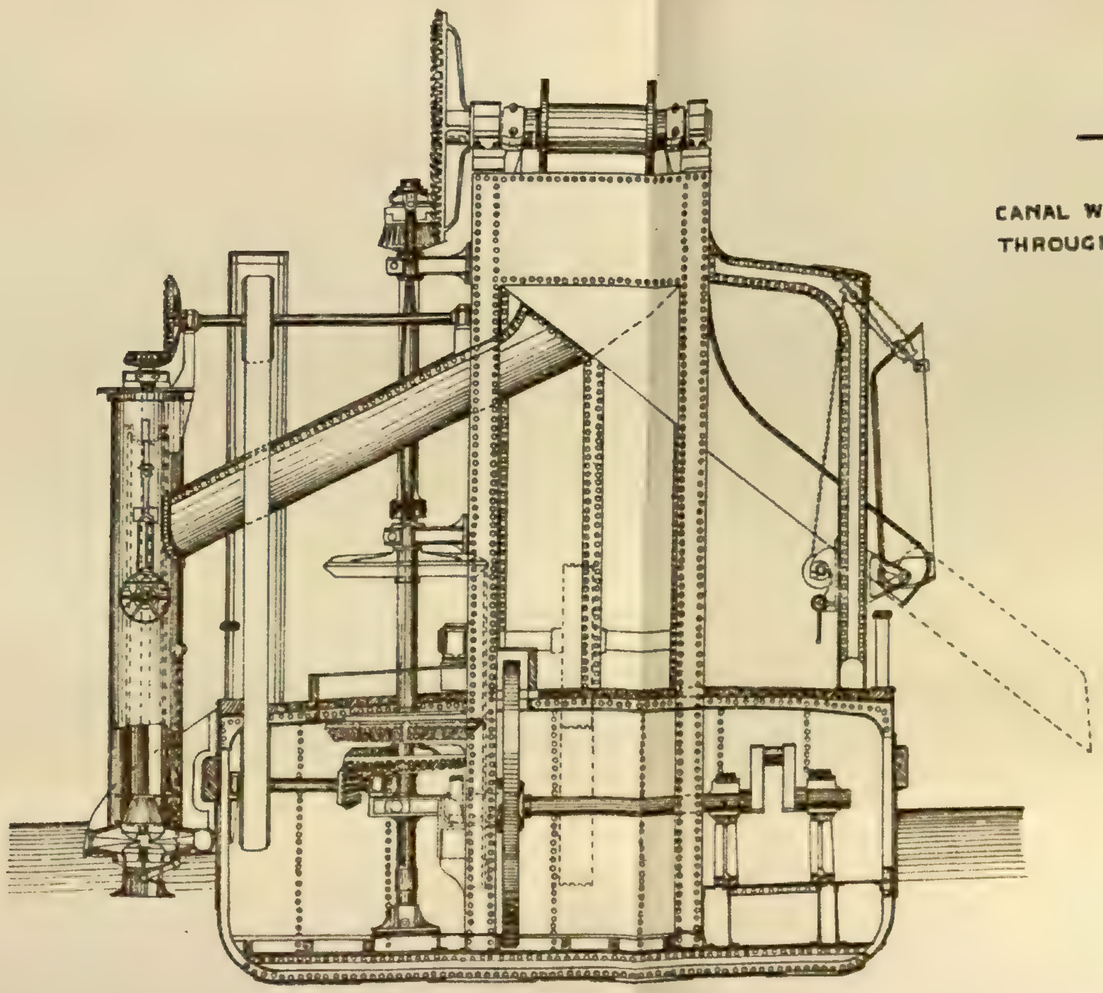
USED AT AMSTERDAM SHIP CANAL

1870.







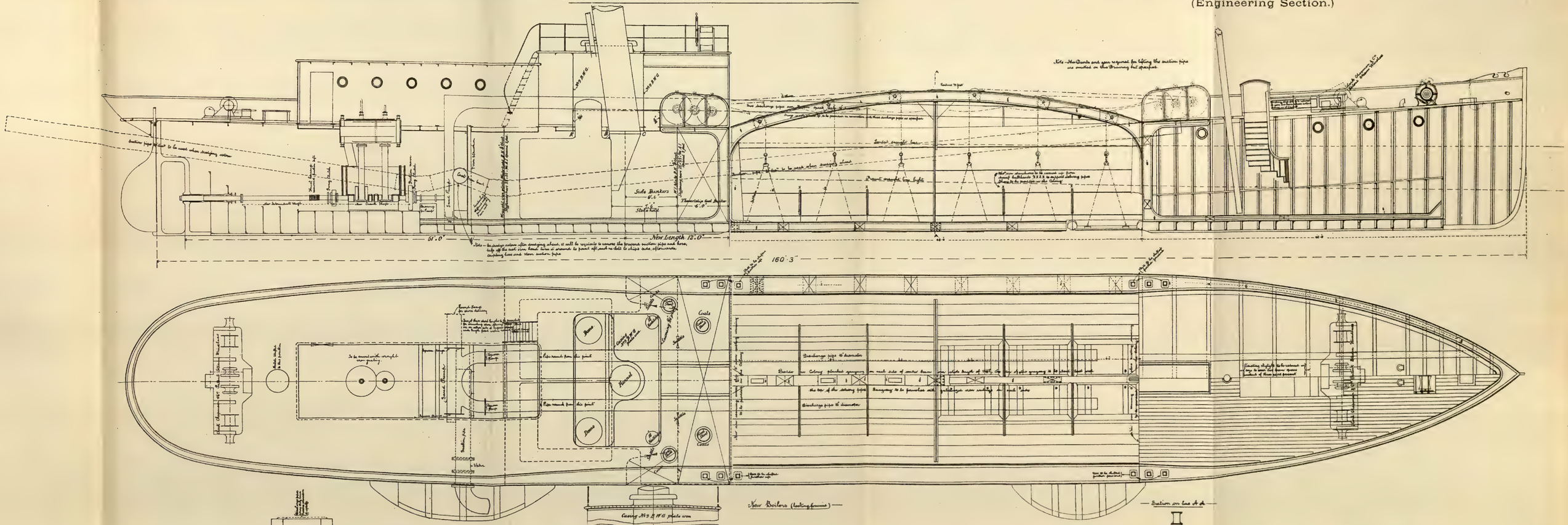


LADDER DREDGE

USED AT AMSTERDAM

CANAL WITH PUMP ATTACHED FOR FORCING SAND THROUGH PIPES TO SHORE.

NEW SOUTH WALES — PUMP HOPPER DREDGER "JUNO" — PLAN SHEWING ALTERATIONS REQUIRED TO CONVERT THE EXISTING — STEAM HOPPER BARGE "JUNO" INTO A PUMP HOPPER DREDGER



Note:– Parts tinted pink shew imported work
Do blue do new portion of hull.
Beams marked A B C are to be scarfed.

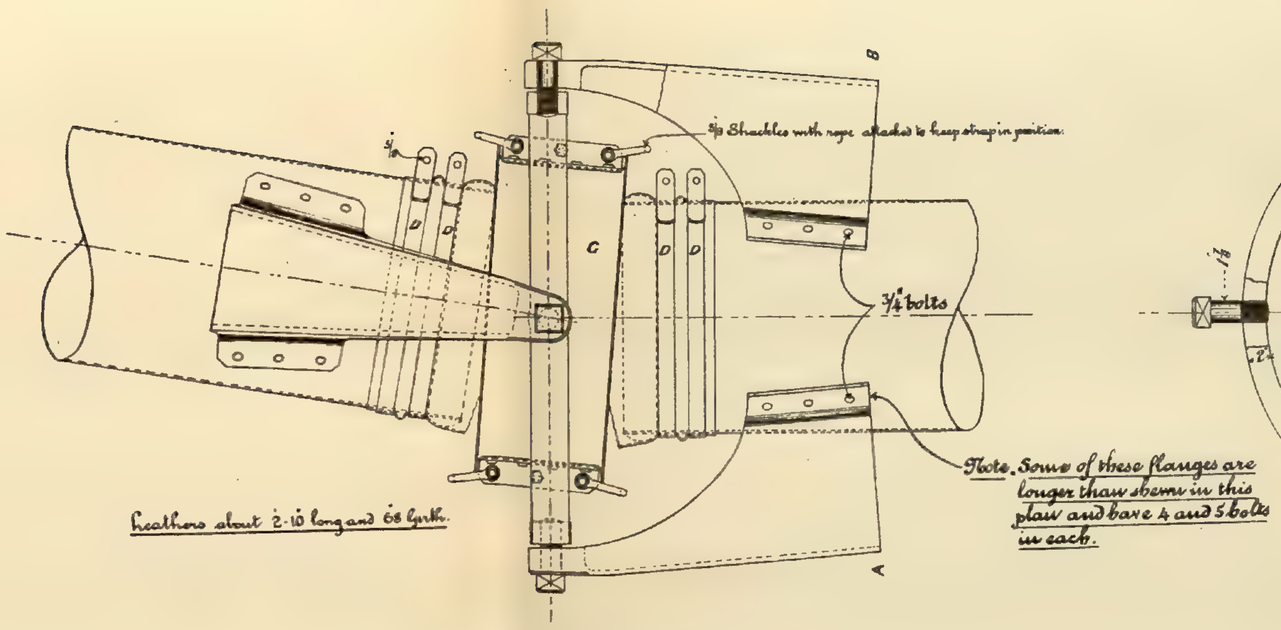
— Dimensions of the "Juno." —

Length between perpendiculars	160·3"
Breadth moulded	29·0
Depth	11·6
Capacity of Hopper in cubic feet	1732

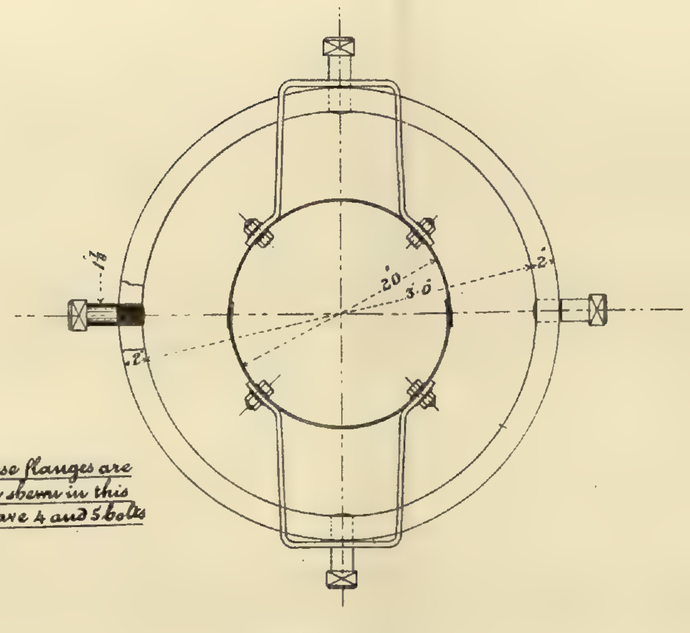
Accommodating Joint for 20 inch Delivery Pipes Sand Pump Dredgers.

Journal Royal Society of N.S.W., Vol XXX, 1896.

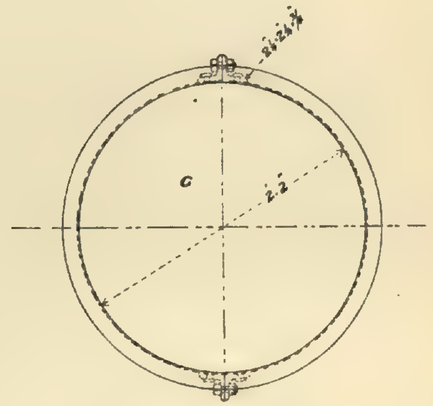
(Engineering Section.)

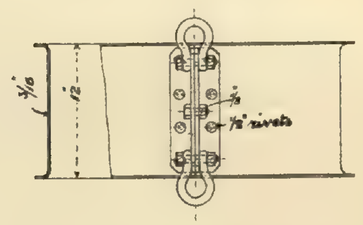


Accommodating Joint with strap over middle part of leather.

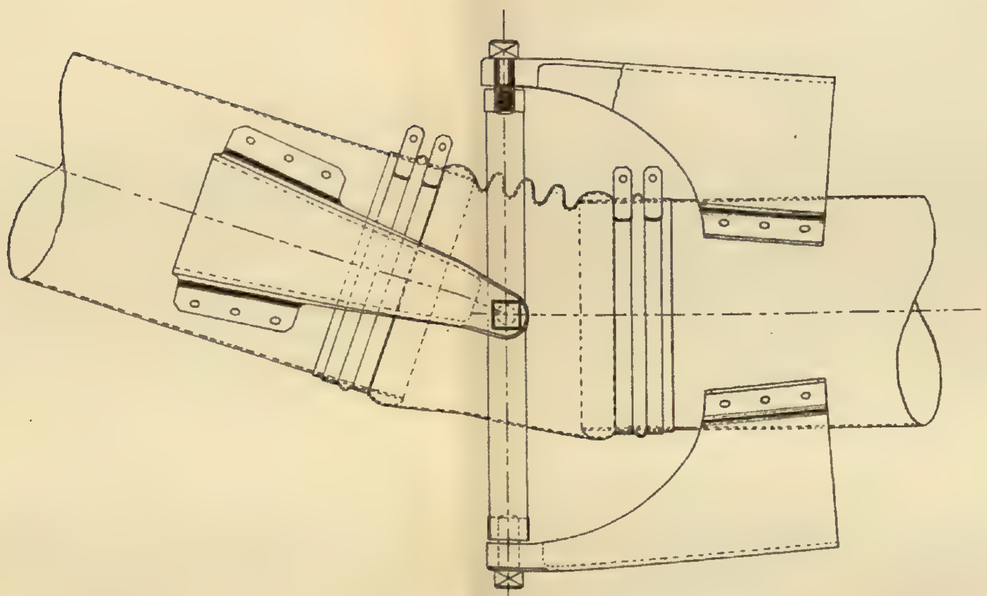


Section at AB and Elevation of Ring

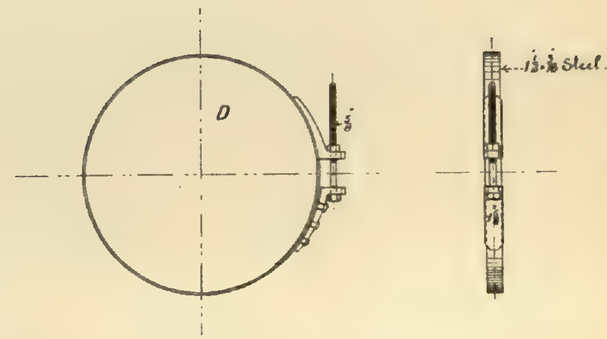




Strap over middle part of leather.



Accommodating Joint without strap over middle part of leather.



Strap for securing the ends of leather to the 20' pipe. Two straps to each end.

PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE, SYDNEY, NEW SOUTH WALES.

— VON SCHMIDT DREDGING MACHINERY. —

— N.S.W. GOVT DREDGER "CROPER". —

— SCALE OF FEET —

0 1 2 3 4 5 6 7 8 9 10

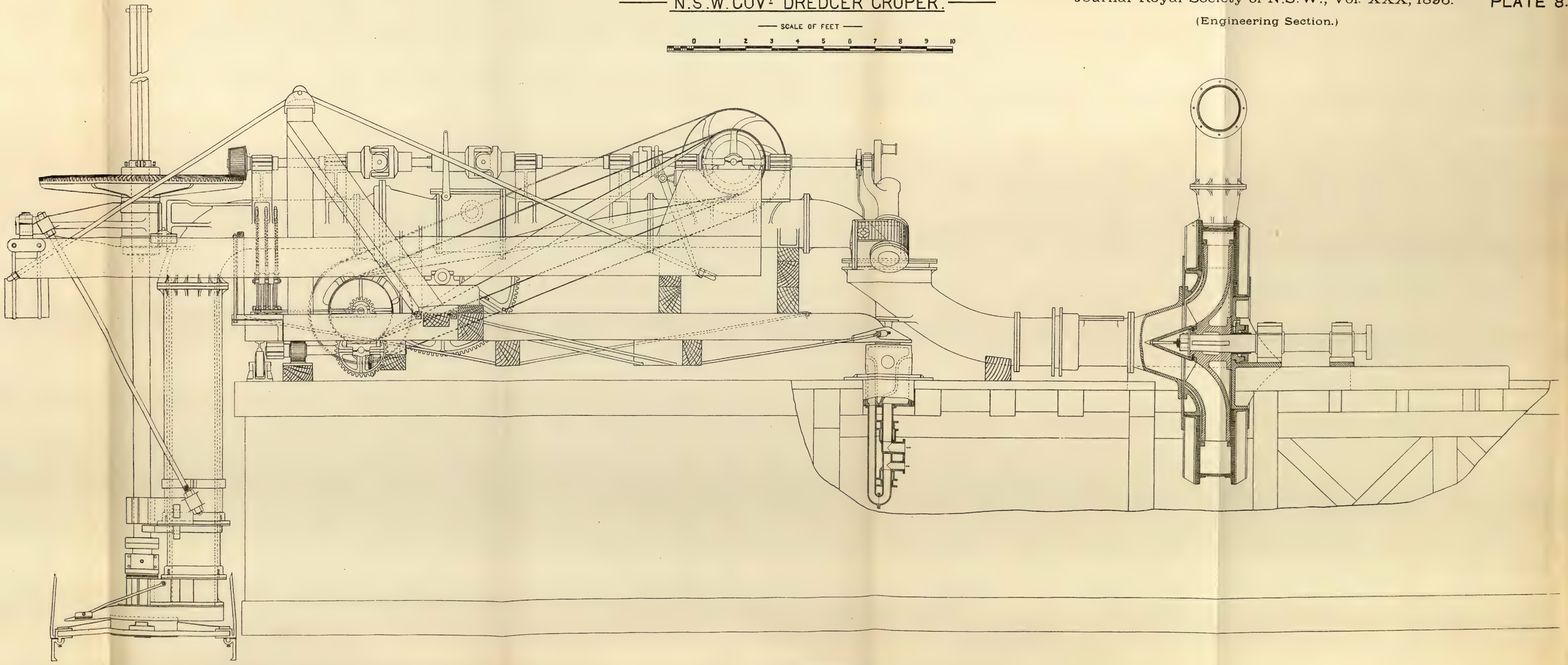
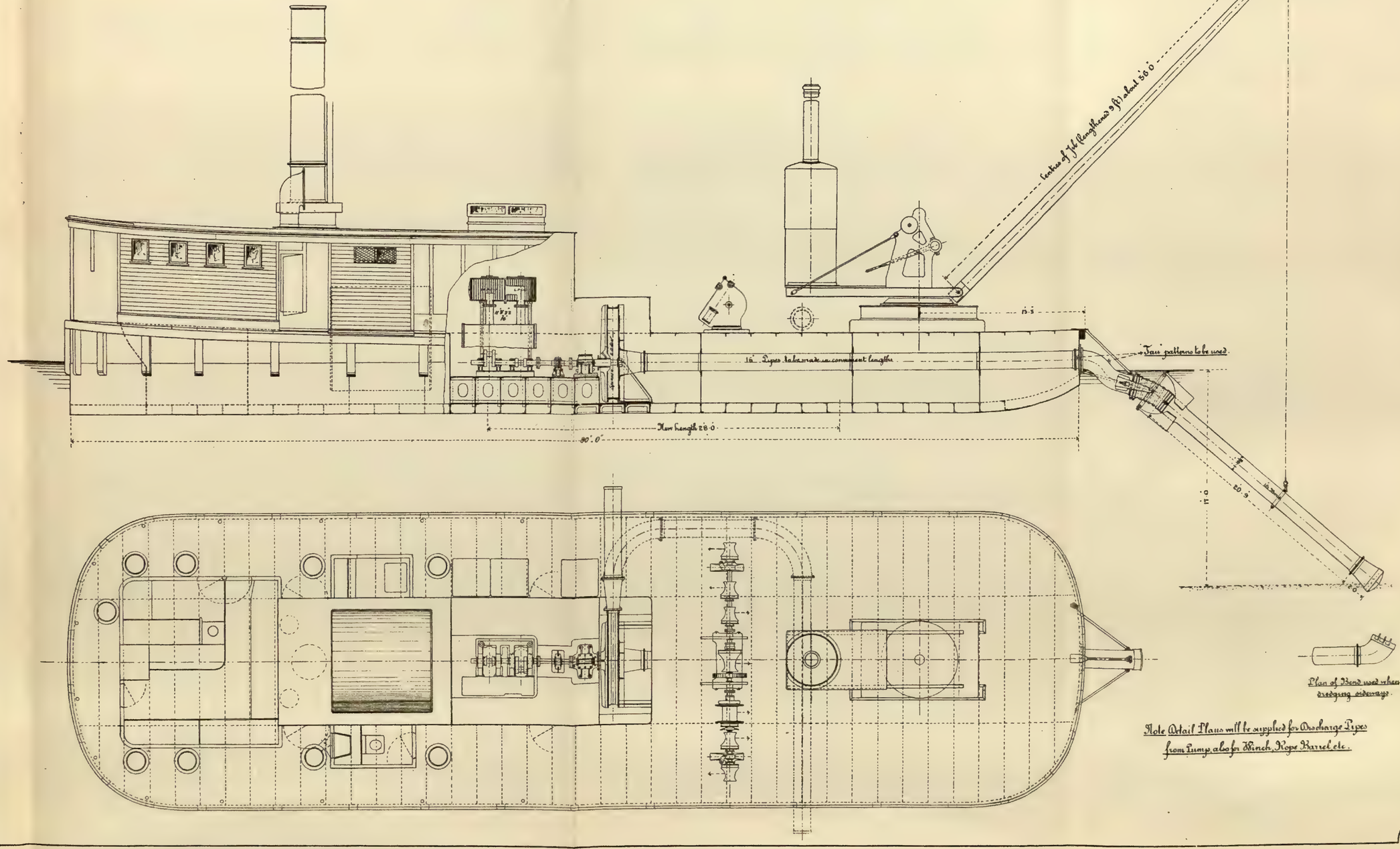


PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE, SYDNEY, NEW SOUTH WALES.

GRAB DREDGE "THETA". LENGTHENING & CONVERSION INTO A PUMP DREDGE.



Note Detail Plans will be supplied for Discharge Pipes from Pump, also for Winch, Rope Barrel etc.

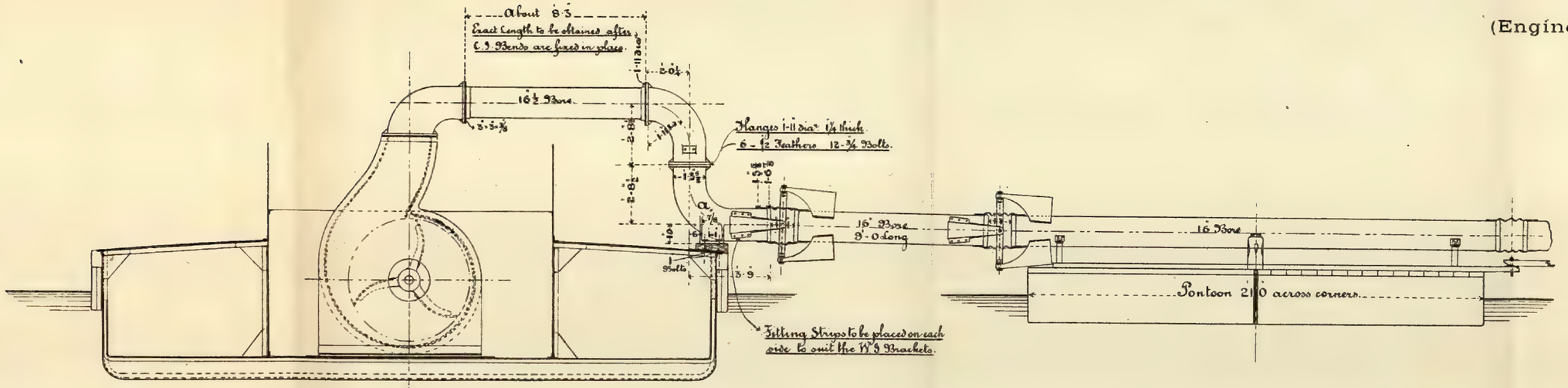
PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE, SYDNEY, NEW SOUTH WALES.

Grab Dredge "Tau". Conversion into a Pump Dredge.

Discharge Pipes from Pump to side of Dredger etc.

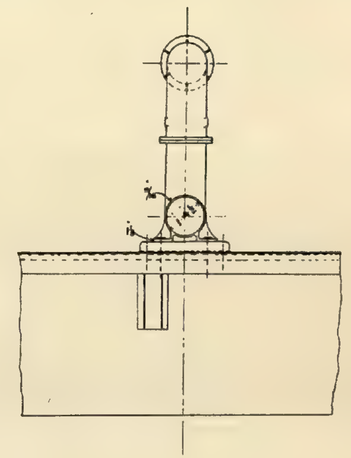
Journal Royal Society of N.S.W., Vol. XXX, 1896.

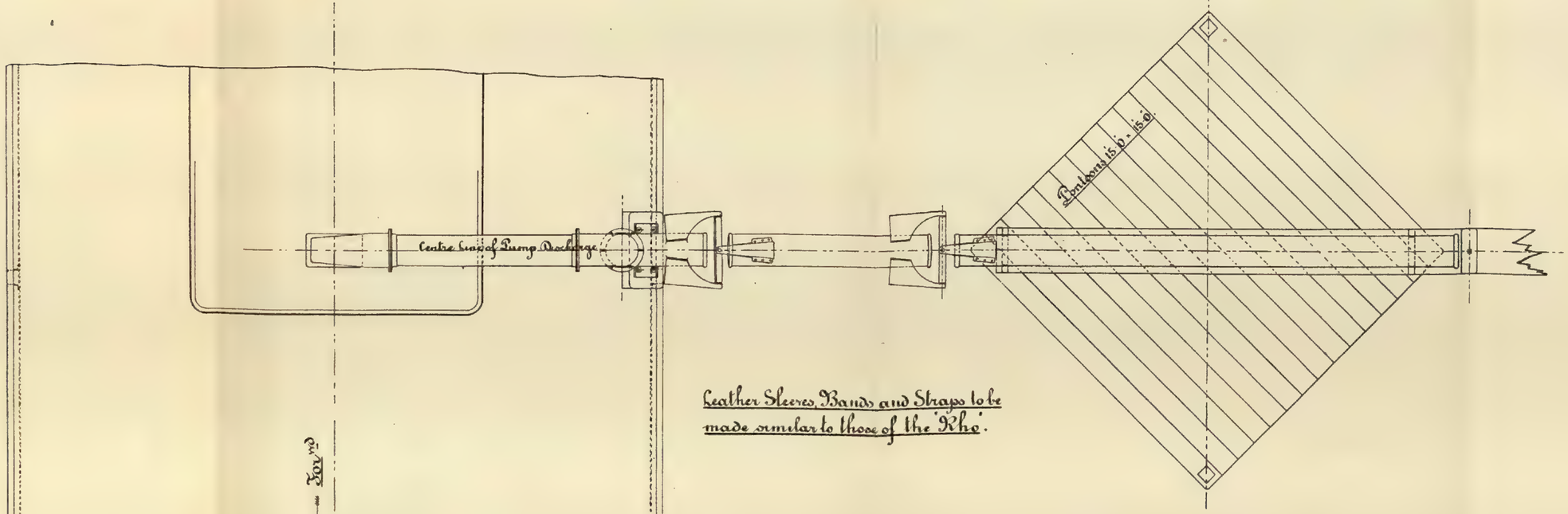
(Engineering Section.)



Section looking Aft.

Note The C.I. Bend a to be securely fastened to the side of Dredge.





Plan.

Leather Sleeves, Bands and Straps to be made similar to those of the 'Rho'.

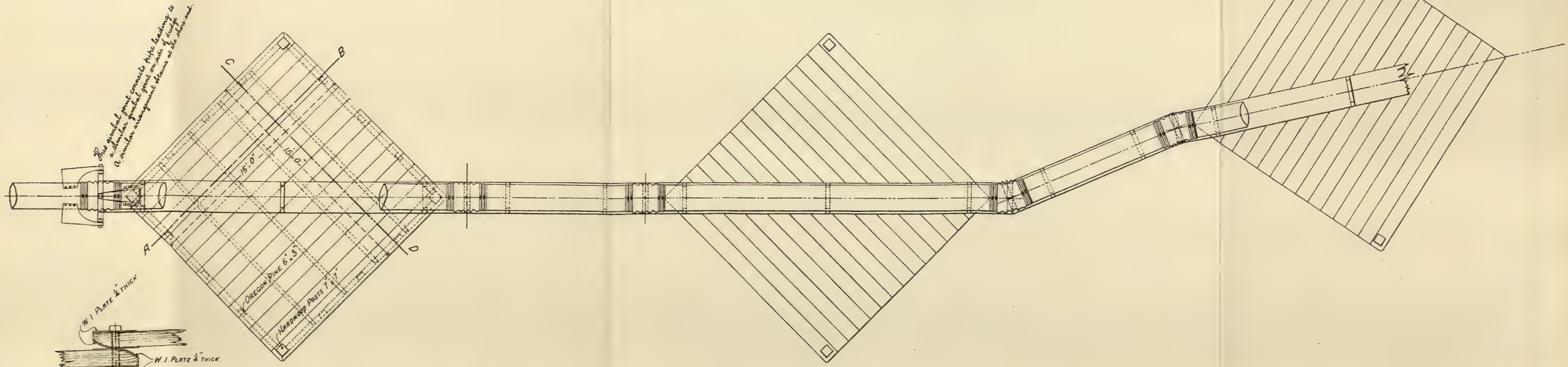
PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE, SYDNEY, NEW SOUTH WALES.

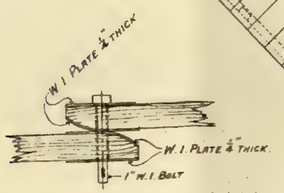
PONTOON BRIDGE FOR CARRYING DELIVERY PIPES FROM SUCTION PUMP — DREDGE.

Journal Royal Society of N.S.W., Vol XXX, 1896

(Engineering Section.)

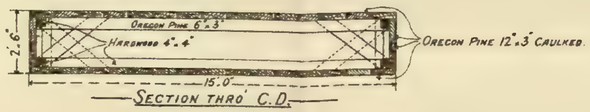
PLATE 11.



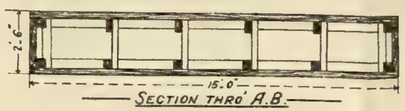


DETAIL OF JOINT AT J J J J

Scale 1½"-1 foot.



SECTION THRO' C.D.



SECTION THRO' A.B.

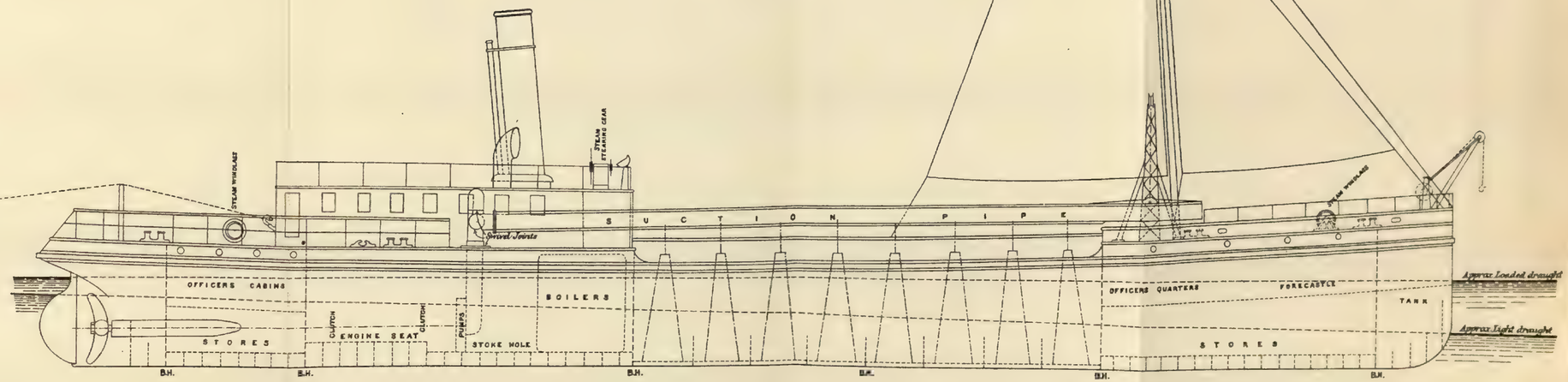
PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE, SYDNEY, NEW SOUTH WALES.

NEW SOUTH WALES.

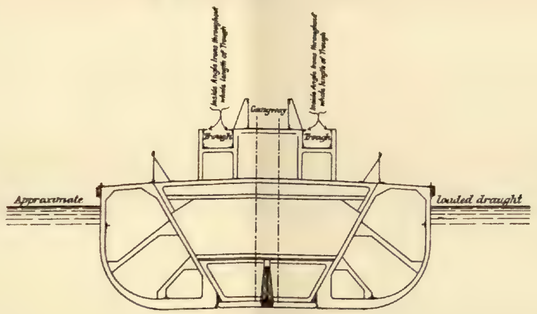
TWIN SCREW PUMP HOPPER DREDGER.

SCALE.

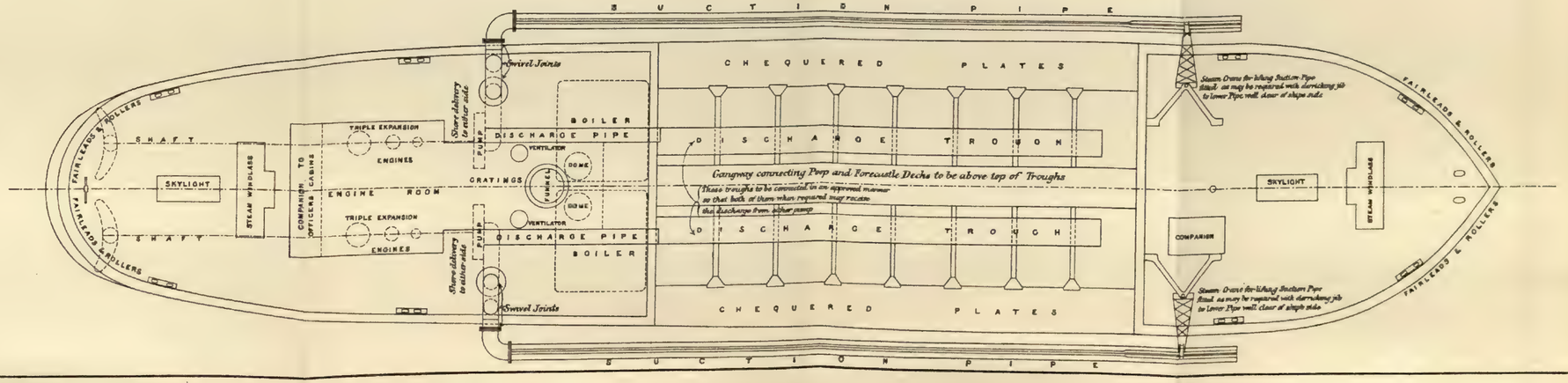
SIDE ELEVATION



MIDSHIP SECTION



PLAN



DIMENSIONS

		ft.	ins.
Length between perpendiculars		160	„ 0
Breadth moulded		32	„ 0
Depth moulded amidships		11	„ 6
Sheer forward		3	„ 9
Sheer aft		2	„ 3
Moulded	Length of Hopper Well	64	„ 0
	Breadth of do at deck	22	„ 0
	Breadth of do at bottom	10	„ 0
Draught with 500 Tons in Hopper		10	„ 0 fore & aft
Draught light (approximate)		8	„ 0 aft, 4' 0" forward

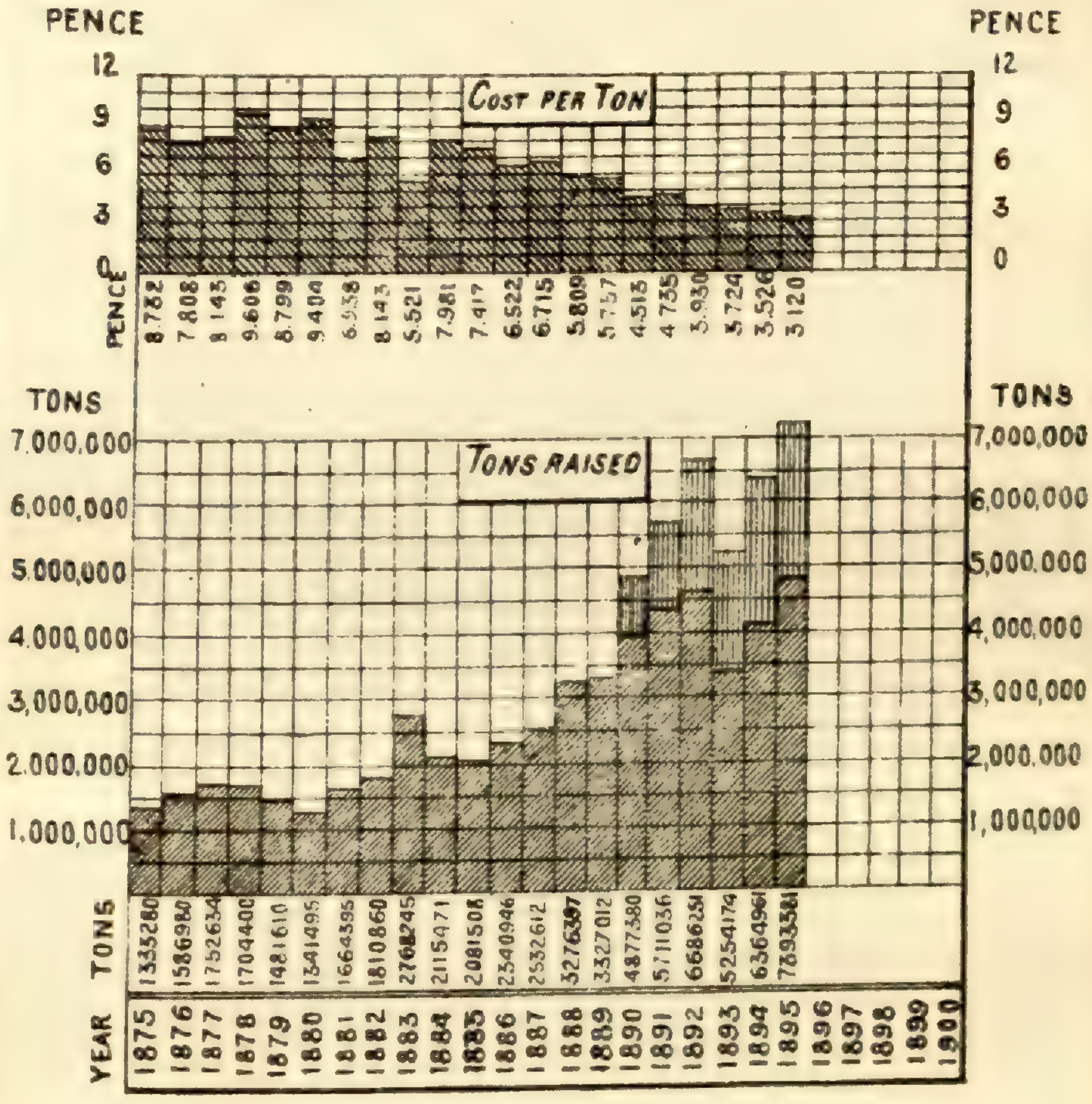
The exact positions of fairleads and rollers both fore and aft, to be determined hereafter.

PHOTO-LITHOGRAPHED AT THE GOVT. PRINTING OFFICE.

HARBOURS AND RIVERS DEPT N.S.W.

DIAGRAM SHEWING TOTAL DREDGING OPERATIONS

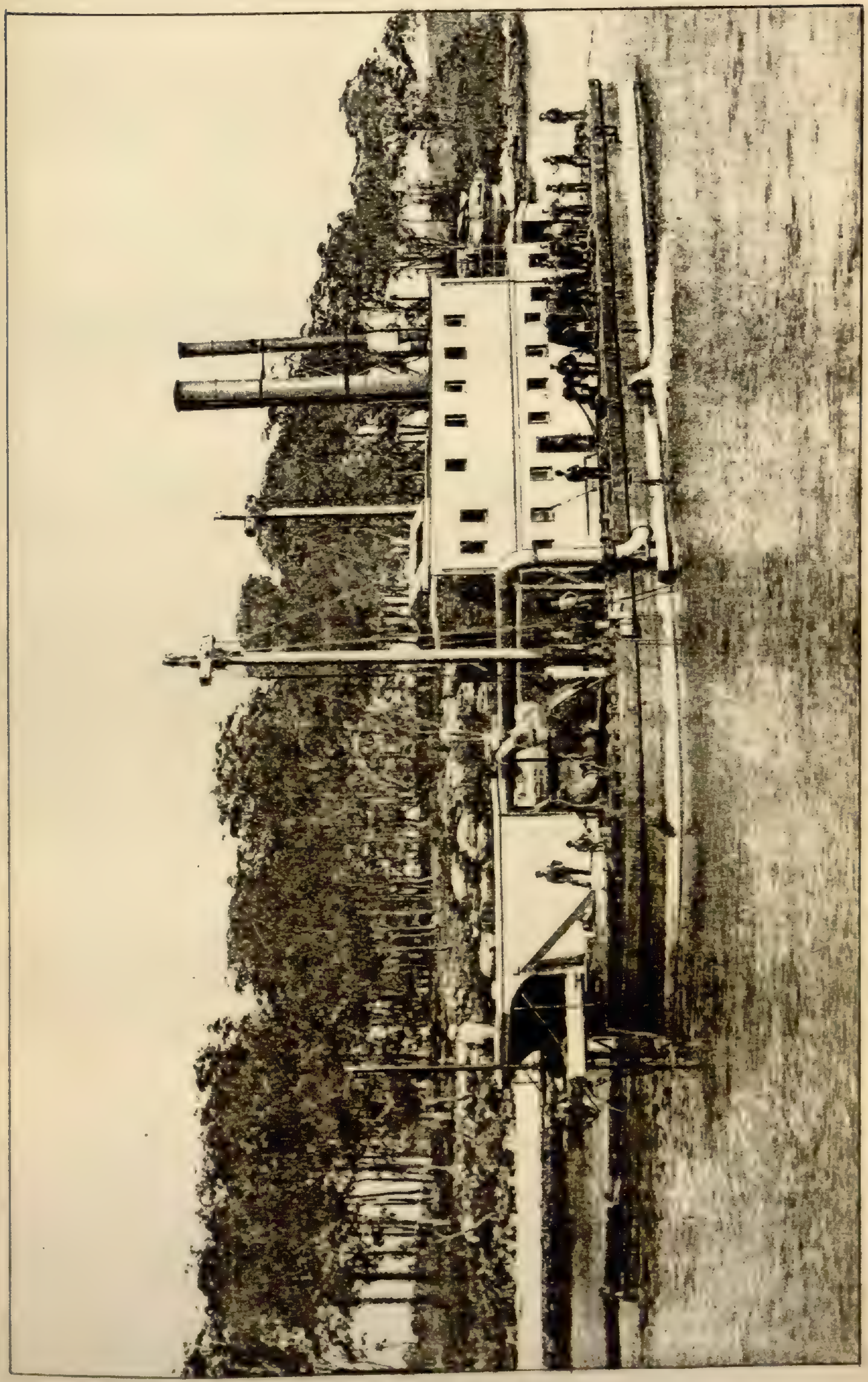
FROM 1875 TO 1895



shews Work done by Ladder and Grab Dredges

" " Sand Pump Dredges

Year 1893 several Dredges out of Commission



EXCHANGES AND PRESENTATIONS

MADE BY THE

ROYAL SOCIETY OF NEW SOUTH WALES, 1896.

The Journal and Proceedings of the Royal Society of N.S.W. for 1896 Vol. xxx., has been transmitted to the Institutions hereunder mentioned :—

The Smithsonian Institution, Washington, United States, America, and Messrs. George Robertson & Co., 17 Warwick Square, Paternoster Row, London, E.C., have kindly undertaken to receive and forward to Sydney all communications and parcels intended for the Royal Society of New South Wales.

Presentations to the Society are acknowledged by letter, and in the Society's Annual Volume.

* Exchanges of Publications have been received from the Societies and Institutions distinguished by an asterisk.

Africa.

1 Tunis ... ...*Institut de Carthage.

Argentine Republic.

2 Cordoba ... ...*Academia Nacional de Ciencias.
3 La Plata... ...*Directeur-Général de Statistique de la Province de Buénos Ayres.
4 ,, ...*Museo de La Plata, Provincia de Buenos Aires.

Austria—Hungary.

5 Agram (Zagrab) ...*Société Archéologique Croate.
6 Bistritz (in Siebenbürgen) } *Direction der Gewerbeschule.
7 Cracow ... ...*Académie des Sciences.
8 Gratz ... ...*Naturwissenschaftliche Vereins für Steiermark in Graz.
9 Prague ... ...*Königlich Böhmische Gesellschaft der Wissenschaften.
10 Trencsin ... ...*Naturwissenschaftliche Verein des Trencsiner Komitates.
11 Trieste ... ...*Museo Civico di Storia Naturale.
12 ,, ...*Società Adriatica di Scienze Naturali.
13 Vienna ... .. *Anthropologische Gesellschaft.
14 ,, ...*Kaiserliche Akademie der Wissenschaften.
15 ,, ...*K. K. Central-Anstalt für Meteorologie und Erdmagnetismus.
16 ,, ...*K. K. Geographische Gesellschaft.
17 ,, ...*K. K. Geologische Reichsanstalt.
18 ,, ...*K. K. Gradmessungs-Bureau.
19 ,, ...*K. K. Naturhistorische Hofmuseums.
20 ,, ...*K. K. Zoologisch-Botanische Gesellschaft.
21 ,, ...*Section für Naturkunde des Osterreichischen-Touristen Club.

Belgium.

22 Brussels ... ...*Académie Royale des Sciences, des Lettres et de Beaux Arts.

23	Brussels	...	...*Musée Royale d'Histoire Naturelle de Belgique.
24	,,	...	...*Observatoire Royale de Bruxelles.
25	,,	...	...*Société Royale Malacologique de Belgique.
26	Liége	...	...*Société Géologique de Belgique.
27	,,	...	...*Société Royale des Sciences de Liége.
28	Luxembourg		...*Institut Royale Grand-Ducal de Luxembourg.
29	Mons	...	...*Société des Sciences, des Arts et des Lettres du Hainaut.

Brazil.

30	Rio de Janeiro		...*Observatoire Impérial de Rio de Janeiro.

Chili.

31	Santiago	...	...*Sociedad Cientifica Alemana.

Denmark.

32	Copenhagen		...*Société Royale des Antiquaires du Nord.

France.

33	Bordeaux	...	...*Académie Nationale des Sciences, Belles-Lettres et Arts.
34	Caen	...	...*Académie Nationale des Sciences, Arts et Belles-Lettres.
35	Dijon	...	...*Académie des Sciences, Arts et Belles-Lettres.
36	Havre	...	...*Société Géologique de Normandie.
37	Lille	...	...*Société Géologique du Nord.
38	Marseilles		...*Faculté des Sciences de Marseille.
39	Montpellier		...*Académie des Sciences et Lettres.
40	Nantes	...	...*Société des Sciences Naturelles de l'Ouest de la France.
41	Paris	...	...*Académie des Sciences de l'Institut de France.
42	,,	...	... Bibliothèque de l'Université à la Sorbonne.
43	,,	...	...*Comptoir Géologique de Paris.
44	,,	...	...*Depot des Cartes et Plans de la Marine.
45	,,	...	...*Ecole d' Anthropologie de Paris.
46	,,	...	...*Ecole Nationale des Mines.
47	,,	...	... Ecole Normale Supérieure.
48	,,	...	...*Ecole Polytechnique.
49	,,	...	... Faculté de Médecine de Paris.
50	,,	...	...**Feuille des Jeunes Naturalistes.*
51	,,	...	...*Institut Pasteur.
52	,,	...	...*Musée d'Histoire Naturelle.
53	,,	...	...*Ministère de l'Instruction Publique, des Beaux Arts, et des Cultes.
54	,,	...	...*Observatoire de Paris.
55	,,	...	...**Revue de l' Aéronautique.*
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57	,,	...	...*Société d'Anatomie.
58	,,	...	...*Société d' Anthropologie.
59	,,	...	...*Société de Biologie.
60	,,	...	... Société de Chirurgie de Paris.
61	,,	...	...*Société d' Encouragement pour l' Industrie Nationale.
62	,,	...	...*Société Entomologique de France.
63	,,	...	...*Société Française de Minéralogie.

64 PARIS ... ...*Société Française de Physique.
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66 „ ... ...*Société Géologique de France.
67 „ ... ... Société Météorologique de France.
68 „ ... ... Société Philotechnique.
69 „ ... ...*Société Zoologique de France.
70 ST. ETIENNE ...*Société de l' Industrie Minérale.
71 TOULOUSE ...*Académie des Sciences, Inscriptions et Belles-Lettres.
72 VILLEFRANCHE-SUR-MER (Alp. Mar.) ... } Laboratoire de Zoologie.

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73 BREMEN .. ...*Naturwissenschaftliche Vereine zu Bremen.
74 BERLIN ... ... Deutsche Chemische Gesellschaft.
75 „ ... ...*Gesellschaft für Erdkunde.
76 „ ... ...*Königlich Preussische Akademie der Wissenschaften.
77 „ .. ...*Königlich Preussische Meteorologische Instituts.
78 BONN ... ...*Naturhistorischen Vereins der Preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück.
79 BRUNSWICK ...*Vereins für Naturwissenschaft zu Braunschweig.
80 CARLSRUHE ...*Grossherzoglich-Badische Polytechnische Schule.
81 „ ...*Naturwissenschaftlicher Verein zu Carlsruhe.
82 CASSELL ... ...*Verein für Naturkunde.
83 CHEMNITZ ...*Naturwissenschaftliche Gesellschaft zu Chemnitz.
84 DRESDEN ... ...*Königliches Mineralogisch Geologische und Praehistorisches Museum.
85 „ ... ...*Offentliche Bibliothek.
86 „ ... ...*Statistische Bureau des Ministeriums des Innern zu Dresden.
87 „ ... ...*Vereins für Erdkunde zu Dresden.
88 ELBERFELD ...*Naturwissenschaftlicher Verein in Elberfeld.
89 FRANKFURT A/M ...*Senckenbergische Naturforschende Gesellschaft.
90 FREIBERG (Saxony) Königlich-Sächsische Berg-Akademie.
91 FREIBURG (Baden) *Naturforschende Gesellschaft.
92 GIESSEN ... ...*Oberhessische Gesellschaft für Natur-und-Heilkunde.
93 GÖRLITZ ... .. *Naturforschende Gesellschaft in Görlitz.
94 GÖTTINGEN ...*Königliche Gesellschaft der Wissenschaften in Göttingen.
95 HALLE, A.S. ...*Kaiserliche Leopoldina—Carolina Akademie der Deutschen Naturforscher.
96 HAMBURG... ...*Deutsche Meteorologische Gesellschaft.
97 „ ... ...*Deutsche Seewarte.
98 „ ... ...*Geographische Gesellschaft in Hamburg.
99 „ ... ...*Naturhistorische Museum.
100 „ ... ...*Verein für Naturwissenschaftliche Unter-haltung in Hamburg.
101 HEIDELBERG ...*Naturhistorisch Medicinische Verein zu Heidelberg.
102 JENA ... ...*Medicinisch Naturwissenschaftliche Gesellschaft.
103 KÖNIGSBERG ...*Königliche Physikalisch-Okonomische Gesellschaft.

104 LEIPZIG ... ...*Königliche Sächsische Gesellschaft der Wissenschaften.
105 „ ... ...*Vereins für Erdkunde.
106 LUBECK ... ...*Naturhistorische Museum.
107 MARBURG... ...*Gesellschaft zur Beförderung der gesammten Naturwissenschaften in Marburg.
108 „ ... ...*University.
109 METZ ... ...*Vereins für Erdkunde zu Metz.
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116 BIRMINGHAM ...*Birmingham and Midland Institute.
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120 CAMBRIDGE ...*Philosophical Society.
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124 KEW ... ...*Royal Gardens.
125 LEEDS ... ...*Leeds Philosophical and Literary Society.
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127 LIVERPOOL ...*Literary and Philosophical Society.
128 LONDON ... ...*Aëronautical Society of Great Britain.
129 „ ... ... Agent-General (two copies).
130 „ ... ...*Anthropological Institute of Great Britain and Ireland.
131 „ ... ...*British Museum (Natural History).
132 „ ... ... Chemical Society.
133 „ ... ... Colonial Office, Downing Street.
134 „ ... ...*Editor, *Encyclopædia Britannica*, 4 Soho Square, W.
135 „ ... ...*Geological Society.
136 „ ... ... Institute of Chemistry of Great Britain and Ireland.
137 „ ... ...*Institution of Civil Engineers.
138 „ ... ...*Institution of Mechanical Engineers.
139 „ ... ...*Institution of Naval Architects.
140 „ ... ...*Iron and Steel Institute.
141 „ ... ...*Library, South Kensington Museum.
142 „ ... ...*Linnean Society.
143 „ ... ... London Institution.
144 „ ... ...*Lords Commissioners of the Admiralty.
145 „ ... ...*Meteorological Office.
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147 „ ... ... Museum of Practical Geology.
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150	London ...	...*Physical Society of London.
151	,, ...	...*Quekett Microscopical Club.
152	,, ...	...*Royal Agricultural Society of England.
153	,, ...	...*Royal Astronomical Society.
154	,, ...	...*Royal College of Physicians.
155	,, ...	...*Royal College of Surgeons.
156	,, ...	...*Royal Colonial Institute.
157	,, ...	...*Royal Geographical Society.
158	,, ...	...*Royal Historical Society.
159	,, ...	...*Royal Institution of Great Britain.
160	,, ...	...*Royal Meteorological Society.
161	,, ...	...*Royal Microscopical Society.
162	,, ...	... Royal School of Mines.
163	,, ...	...*Royal Society.
164	,, ...	... Royal Society of Literature.
165	,, ...	...*Royal United Service Institution.
166	,, ...	...*Sanitary Institute of Great Britain.
167	,, ...	...*Society of Arts.
168	,, ...	... University of London.
169	,, ..	...*War Office—(Intelligence Division).
170	,, ...	.. *Zoological Society.
171	Manchester	...*Conchological Society.
172	,,	...*Literary and Philosophical Society.
173	,,	...*Manchester Geological Society.
174	,,	... Owens College.
175	Mirfield	..*Yorkshire Geological and Polytechnic Society.
176	Newcastle-upon-Tyne...	...*Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne.
177	,,	...*North of England Institute of Mining and Mechanical Engineers.
178	,,	... Society of Chemical Industry.
179	Oxford ...	...*Bodleian Library.
180	,, ...	...*Radcliffe Library.
181	,, ...	...*Radcliffe Observatory.
182	Penzance	...*Royal Geological Society of Cornwall.
183	Plymouth	...*Plymouth Institution and Devon and Cornwall Natural History Society.
184	Windsor ...	... The Queen's Library.

CAPE OF GOOD HOPE.

185	Cape Town	...*South African Philosophical Society.

CEYLON.

186	Colombo ...	...*Royal Asiatic Society, (Ceylon Branch).

DOMINION OF CANADA.

187	Halifax, (Nova Scotia)	*Nova Scotian Institute of Science.
188	Hamilton (Ont.)	*Hamilton Association.
189	Montreal	...*Natural History Society of Montreal.
190	,, ...	...*Royal Society of Canada.
191	Ottawa ...	...*Geological and Natural History Survey of Canada.
192	Quebec ...	...*Literary and Historical Society.
193	Toronto ...	...*Canadian Institute.
194	,, ...	...*University.
195	Winnipeg	...*Manitoba Historical and Scientific Society.

INDIA.

196 CALCUTTA ...*Asiatic Society of Bengal.
197 „ ... ...*Geological Survey of India.

IRELAND.

198 DUBLIN ... ...*Royal Dublin Society.
199 „ ... ...*Royal Geological Society of Ireland.
200 „ ... ...*Royal Irish Academy.

JAMAICA.

201 KINGSTON... ...*Institute of Jamaica.

MAURITIUS.

202 PORT LOUIS ...*Royal Society of Arts and Sciences.
203 „ ... Société d'Acclimatation de l' Ile Maurice.

NEW SOUTH WALES.

204 RICHMOND ... Hawkesbury Agricultural College.
205 SYDNEY ... ...*Australian Museum.
206 „ ... ...*Department of Mines and Agriculture.
207 „ ... ...*Department of Public Instruction.
208 „ ... ...*Department of Public Works.
209 „ ... ...*Engineering Association of New South Wales.
210 „ ... ...*Government Statistician.
211 „ ... ...*Institution of Surveyors, N. S. Wales.
212 „ ... ...*Linnean Society of New South Wales.
213 „ ... ...*Mining Department.
214 „ ... ... N. S. Wales Government Railways Institute.
215 „ ... ...*Observatory.
216 „ ... ...*Public Library.
217 „ ... ...*Royal Geographical Society of Australasia (New South Wales Branch).
218 „ ... ... School of Arts.
219 „ ... ...*Technological Museum.
220 „ ... ...*United Service Institution of New South Wales.
221 „ ... ...*University.

NEW ZEALAND.

222 AUCKLAND ...*Auckland Institute.
223 CHRISTCHURCH ... Philosophical Institute of Canterbury.
224 DUNEDIN ... ... Otago Institute.
225 WELLINGTON ...*Colonial Museum.
226 „ ...*New Zealand Institute.
227 „ ...*Polynesian Society.

QUEENSLAND.

228 BRISBANE... .. *Acclimatization Society of Queensland.
229 „ ... ...*Geological Survey of Queensland.
230 „ ... ... Parliamentary Library.
231 „ ... ...*Queensland Museum.
232 „ ... ...*Royal Geographical Society of Australasia (Queensland Branch).
233 „ ... ...*Royal Society of Queensland.

SCOTLAND.

234 ABERDEEN ...*University.

235	EDINBURGH	...	...*Edinburgh Geological Society.
236	,,	...	...*Highland and Agricultural Society of Scotland.
237	,,	...	...*Royal Botanic Garden.
238	,,	...	...*Royal Observatory.
239	,,	...	...*Royal Physical Society.
240	,,	...	...*Royal Scottish Geographical Society.
241	,,	...	...*Royal Society.
242	,,	...	...*University.
243	GLASGOW	...	...*Geological Society of Glasgow.
244	,,	...	...*Philosophical Society of Glasgow.
245	,,	...	...*University.
246	ST. ANDREWS		..*University.

SOUTH AUSTRALIA.

247	ADELAIDE	...	...*Geological Survey of South Australia.
248	,,	...	... Government Botanist.
249	,,	...	...*Government Printer.
250	,,	...	...*Observatory.
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1897.

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The Society's House, 5 Elizabeth Street,
Sydney, 31st December, 1896.

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We are, Sir,

Your obedient Servants,

J. W. GRIMSHAW
G. H. KNIBBS ..... } *Hon. Secs.*

PUBLICATIONS.

—o—

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.

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EXCHANGES AND PRESENTATIONS

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Argentine Republic.

2 CORDOBA ... ...*Academia Nacional de Ciencias.
3 LA PLATA... ...*Directeur-Général de Statistique de la Province de Buénos Ayres.
4 ,, ...*Museo de La Plata, Provincia de Buenos Aires.

Austria—Hungary.

5 AGRAM (Zagrab) ...*Société Archéologique Croate.
6 BISTRITZ (in Siebenbürgen) } *Direction der Gewerbeschule.
7 CRACOW ... ...*Académie des Sciences.
8 GRATZ ... ...*Naturwissenschaftliche Vereins für Steiermark in Graz.
9 PRAGUE ... ...*Königlich Böhmische Gesellschaft der Wissenschaften.
10 TRENCSIN ... ...*Naturwissenschaftliche Verein des Trencsiner Komitates.
11 TRIESTE ... ...*Museo Civico di Storia Naturale.
12 ,, ...*Società Adriatica di Scienze Naturali.
13 VIENNA ... .. *Anthropologische Gesellschaft.
14 ,, ...*Kaiserliche Akademie der Wissenschaften.
15 ,, ...*K. K. Central-Anstalt für Meteorologie und Erdmagnetismus.
16 ,, ...*K. K. Geographische Gesellschaft.
17 ,, ...*K. K. Geologische Reichsanstalt.
18 ,, ...*K. K. Gradmessungs-Bureau.
19 ,, ...*K. K. Naturhistorische Hofmuseums.
20 ,, ...*K. K. Zoologisch-Botanische Gesellschaft.
21 ,, ...*Section für Naturkunde des Osterreichischen-Touristen Club.

Belgium.

22 BRUSSELS ... . *Académie Royale des Sciences, des Lettres et de Beaux Arts.

23 Brussels ... ...*Musée Royale d'Histoire Naturelle de Belgique.
24 „ ... ...*Observatoire Royale de Bruxelles.
25 „ ... ...*Société Royale Malacologique de Belgique.
26 Liége ... ...*Société Géologique de Belgique.
27 „ ... ...*Société Royale des Sciences de Liége.
28 Luxembourg ...*Institut Royale Grand-Ducal de Luxembourg.
29 Mons ... ...*Société des Sciences, des Arts et des Lettres du Hainaut.

Brazil.

30 Rio de Janeiro ...*Observatoire Impérial de Rio de Janeiro.

Chili.

31 Santiago ... ...*Sociedad Cientifica Alemana.

Denmark.

32 Copenhagen ...*Société Royale des Antiquaires du Nord.

France.

33 Bordeaux ... ...*Académie Nationale des Sciences, Belles-Lettres et Arts.
34 Caen ... ...*Académie Nationale des Sciences, Arts et Belles-Lettres.
35 Dijon ... ...*Académie des Sciences, Arts et Belles-Lettres.
36 Havre ... ...*Société Géologique de Normandie.
37 Lille ... ...*Société Géologique du Nord.
38 Marseilles ...*Faculté des Sciences de Marseille.
39 Montpellier ...*Académie des Sciences et Lettres.
40 Nantes ... ...*Société des Sciences Naturelles de l'Ouest de la France.
41 Paris ... ...*Académie des Sciences de l'Institut de France.
42 „ ... ... Bibliothèque de l'Université à la Sorbonne.
43 „ ... ...*Comptoir Géologique de Paris.
44 „ ... ...*Depot des Cartes et Plans de la Marine.
45 „ ... ...*Ecole d' Anthropologie de Paris.
46 „ ... ...*Ecole Nationale des Mines.
47 „ ... ... Ecole Normale Supérieure.
48 „ ... ...*Ecole Polytechnique.
49 „ ... ... Faculté de Médecine de Paris.
50 „ ... ...**Feuille des Jeunes Naturalistes.*
51 „ ... ...*Institut Pasteur.
52 „ ... ...*Musée d'Histoire Naturelle.
53 „ ... ...*Ministère de l'Instruction Publique, des Beaux Arts, et des Cultes.
54 „ ... ...*Observatoire de Paris.
55 „ ... ...**Revue de l' Aéronautique.*
56 „ ... ... Société Botanique.
57 „ ... ...*Société d'Anatomie.
58 „ ... ...*Société d' Anthropologie.
59 „ ... ...*Société de Biologie.
60 „ ... ... Société de Chirurgie de Paris.
61 „ ... ...*Société d' Encouragement pour l' Industrie Nationale.
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63 „ ... ...*Société Française de Minéralogie.

64 PARIS ....*Société Française de Physique.
65 „ ... ...*Société de Géographie.
66 „ ... ...*Société Géologique de France.
67 „ ... ... Société Météorologique de France.
68 „ ... ... Société Philotechnique.
69 „ ... ...*Société Zoologique de France.
70 ST. ETIENNE ...*Société de l' Industrie Minérale.
71 TOULOUSE ...*Académie des Sciences, Inscriptions et Belles-Lettres.
72 VILLEFRANCHE-SUR-MER (Alp. Mar.) ... } Laboratoire de Zoologie.

Germany.

73 BREMEN .. ...*Naturwissenschaftliche Vereine zu Bremen.
74 BERLIN ... ... Deutsche Chemische Gesellschaft.
75 „ ... ...*Gesellschaft für Erdkunde.
76 „ ... ...*Königlich Preussische Akademie der Wissenschaften.
77 „ ... ...*Königlich Preussische Meteorologische Instituts.
78 BONN ... ...*Naturhistorischen Vereins der Preussischen Rheinlande, Westfalens und des Reg.-Bezirks Osnabrück.
79 BRUNSWICK ...*Vereins für Naturwissenschaft zu Braunschweig.
80 CARLSRUHE ...*Grossherzoglich-Badische Polytechnische Schule.
81 „ ...*Naturwissenschaftlicher Verein zu Carlsruhe.
82 CASSELL ... ...*Verein für Naturkunde.
83 CHEMNITZ ...*Naturwissenschaftliche Gesellschaft zu Chemnitz.
84 DRESDEN ... ...*Königliches Mineralogisch Geologische und Praehistorisches Museum.
85 „ ... ...*Offentliche Bibliothek.
86 „ ... ...*Statistische Bureau des Ministeriums des Innern zu Dresden.
87 „ ... ...*Vereins für Erdkunde zu Dresden.
88 ELBERFELD ...*Naturwissenschaftlicher Verein in Elberfeld.
89 FRANKFURT A/M ...*Senckenbergische Naturforschende Gesellschaft.
90 FREIBERG (Saxony) Königlich-Sächsische Berg-Akademie.
91 FREIBURG (Baden) *Naturforschende Gesellschaft.
92 GIESSEN ... ...*Oberhessische Gesellschaft für Natur-und-Heilkunde.
93 GÖRLITZ ... ...*Naturforschende Gesellschaft in Görlitz.
94 GÖTTINGEN ...*Königliche Gesellschaft der Wissenschaften in Göttingen.
95 HALLE, A.S. ...*Kaiserliche Leopoldina—Carolina Akademie der Deutschen Naturforscher.
96 HAMBURG ... ...*Deutsche Meteorologische Gesellschaft.
97 „ ... ...*Deutsche Seewarte.
98 „ ... ...*Geographische Gesellschaft in Hamburg.
99 „ ... ...*Naturhistorische Museum.
100 „ ... ...*Verein für Naturwissenschaftliche Unter-haltung in Hamburg.
101 HEIDELBERG ...*Naturhistorisch Medicinische Verein zu Heidelberg.
102 JENA ... ...*Medicinisch Naturwissenschaftliche Gesellschaft.
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105 „ ... ...*Vereins für Erdkunde.
106 LUBECK ... ...*Naturhistorische Museum.
107 MARBURG... ...*Gesellschaft zur Beförderung der gesammten Naturwissenschaften in Marburg.
108 „ ... ...*University.
109 METZ ... ...*Vereins für Erdkunde zu Metz.
110 MULHOUSE ...*Société Industrielle de Mulhouse.
111 MUNICH ... ...*Königlich Bayerische Akademie der Wissenschaften in München.
112 „ ... ... Société Botanique Bavaroise.
113 STUTTGART ...*Königliches Statistische Landesamt.
114 „ ... ...*Verein für Vaterländische Naturkunde in Württemberg.
115 „ ... ...*Württembergische Vereins für Handelsgeographie.

Great Britain and the Colonies.

116 BIRMINGHAM ...*Birmingham and Midland Institute.
117 „ ...*Birmingham Natural History and Philosophical Society.
118 BRISTOL ... ...*Bristol Naturalists' Society.
119 CAMBORNE ...*Mining Association and Institute of Cornwall.
120 CAMBRIDGE ...*Philosophical Society.
121 „ ... Public Free Library.
122 „ ...*Union Society.
123 „ .. University Library.
124 KEW ... ...*Royal Gardens.
125 LEEDS ... ...*Leeds Philosophical and Literary Society.
126 „ ... ...*Yorkshire College.
127 LIVERPOOL ...*Literary and Philosophical Society.
128 LONDON ... ...*Aëronautical Society of Great Britain.
129 „ ... ... Agent-General (two copies).
130 „ ... ...*Anthropological Institute of Great Britain and Ireland.
131 „ ... ...*British Museum (Natural History).
132 „ ... ... Chemical Society.
133 „ ... ... Colonial Office, Downing Street.
134 „ ... ...*Editor, *Encyclopædia Britannica*, 4 Soho Square, W.
135 „ ... ...*Geological Society.
136 „ ... ... Institute of Chemistry of Great Britain and Ireland.
137 „ ... ...*Institution of Civil Engineers.
138 „ ... ...*Institution of Mechanical Engineers.
139 „ ... ...*Institution of Naval Architects.
140 „ ... ...*Iron and Steel Institute.
141 „ ... ...*Library, South Kensington Museum.
142 „ ... ...*Linnean Society.
143 „ ... ... London Institution.
144 „ ... ...*Lords Commissioners of the Admiralty.
145 „ ... ...*Meteorological Office.
146 „ ... ...*Mineralogical Society.
147 „ ... ... Museum of Practical Geology.
148 „ ... ... Patent Office Library.
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150	London ...	...*Physical Society of London.
151	,, ...	...*Quekett Microscopical Club.
152	,, ...	..*Royal Agricultural Society of England.
153	,, ...	...*Royal Astronomical Society.
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155	,, ...	...*Royal College of Surgeons.
156	,, ...	...*Royal Colonial Institute.
157	,, ...	...*Royal Geographical Society.
158	,, ...	...*Royal Historical Society.
159	,, ...	...*Royal Institution of Great Britain.
160	,, ...	...*Royal Meteorological Society.
161	,, ...	...*Royal Microscopical Society.
162	,, ...	... Royal School of Mines.
163	,, ...	...*Royal Society.
164	,, ...	... Royal Society of Literature.
165	,, ...	...*Royal United Service Institution.
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171	Manchester	...*Conchological Society.
172	,,	...*Literary and Philosophical Society.
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174	,,	... Owens College.
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178	,,	... Society of Chemical Industry.
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CAPE OF GOOD HOPE.

185	Cape Town	...*South African Philosophical Society.

CEYLON.

186	Colombo ...	...*Royal Asiatic Society, (Ceylon Branch).

DOMINION OF CANADA.

187	Halifax, (Nova Scotia)	*Nova Scotian Institute of Science.
188	Hamilton (Ont.)	*Hamilton Association.
189	Montreal	...*Natural History Society of Montreal.
190	,, ...	...*Royal Society of Canada.
191	Ottawa ...	...*Geological and Natural History Survey of Canada.
192	Quebec ...	...*Literary and Historical Society.
193	Toronto ...	...*Canadian Institute.
194	,, ...	...*University.
195	Winnipeg	...*Manitoba Historical and Scientific Society.

INDIA.

196 CALCUTTA ...*Asiatic Society of Bengal.
197 „ ... ...*Geological Survey of India.

IRELAND.

198 DUBLIN ... ...*Royal Dublin Society.
199 „ ... ...*Royal Geological Society of Ireland.
200 „ ... ...*Royal Irish Academy.

JAMAICA.

201 KINGSTON... ...*Institute of Jamaica.

MAURITIUS.

202 PORT LOUIS ...*Royal Society of Arts and Sciences.
203 „ ... Société d'Acclimatation de l' Ile Maurice.

NEW SOUTH WALES.

204 RICHMOND ... Hawkesbury Agricultural College.
205 SYDNEY ... ...*Australian Museum.
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207 „ ... ...*Department of Public Instruction.
208 „ ... ...*Department of Public Works.
209 „ ... ...*Engineering Association of New South Wales.
210 „ ... ...*Government Statistician.
211 „ ... ...*Institution of Surveyors, N. S. Wales.
212 „ ... ...*Linnean Society of New South Wales.
213 „ ... ...*Mining Department.
214 „ ... ... N. S. Wales Government Railways Institute.
215 „ ... ...*Observatory.
216 „ ... ...*Public Library.
217 „ ... ...*Royal Geographical Society of Australasia (New South Wales Branch).
218 „ ... ... School of Arts.
219 „ ... ...*Technological Museum.
220 „ ... ...*United Service Institution of New South Wales.
221 „ ... ...*University.

NEW ZEALAND.

222 AUCKLAND ...*Auckland Institute.
223 CHRISTCHURCH ... Philosophical Institute of Canterbury.
224 DUNEDIN ... ... Otago Institute.
225 WELLINGTON ...*Colonial Museum.
226 „ ...*New Zealand Institute.
227 „ ...*Polynesian Society.

QUEENSLAND.

228 BRISBANE... .. *Acclimatization Society of Queensland.
229 „ ... ...*Geological Survey of Queensland.
230 „ ... ... Parliamentary Library.
231 „ ... ...*Queensland Museum.
232 „ ... ...*Royal Geographical Society of Australasia (Queensland Branch).
233 „ ... ...*Royal Society of Queensland.

SCOTLAND.

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235 EDINBURGH ...*Edinburgh Geological Society.
236 „ ...*Highland and Agricultural Society of Scotland.
237 „ ...*Royal Botanic Garden.
238 „ ...*Royal Observatory.
239 „ ...*Royal Physical Society.
240 „ ...*Royal Scottish Geographical Society.
241 „ ...*Royal Society.
242 „ ...*University.
243 GLASGOW ...*Geological Society of Glasgow.
244 „ ...*Philosophical Society of Glasgow.
245 „ ...*University.
246 ST. ANDREWS ..*University.

SOUTH AUSTRALIA.

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248 „ ... ... Government Botanist.
249 „ ...*Government Printer.
250 „ ...*Observatory.
251 „ ...*Public Library, Museum, and Art Gallery of South Australia.
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253 „ ...*Royal Society of South Australia.
254 „ ...*University.

STRAITS SETTLEMENTS.

255 SINGAPORE ...*Royal Asiatic Society (Straits Branch).

TASMANIA.

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257 LAUNCESTON ...*Geological Survey of Tasmania.

VICTORIA.

258 BALLARAT ...*School of Mines and Industries.
259 MARYBOROUGH ... District School of Mines, Industries and Science.
260 MELBOURNE ...*Field Naturalists' Club of Victoria.
261 „ ...*Government Botanist.
262 „ ...*Government Statist.
263 „ ...*Mining Department.
264 „ ...*Observatory.
265 „ ...*Public Library.
266 „ ...*Registrar-General.
267 „ ...*Royal Geographical Society of Australasia (Victorian Branch).
268 „ ...*Royal Society of Victoria.
269 „ ...*University.
270 „ ...*Victorian Institute of Surveyors.
271 „ ...*Working Men's College.
272 STAWELL ... ...*School of Mines, Art, Industry, and Science.

WESTERN AUSTRALIA.

273 PERTH ... ...*Museum.

Hayti.

274 PORT-AU-PRINCE ... Société de Sciences et de Géographie.

Italy.

275 Bologna ... ...*R. Accademia delle Scienze dell'Istituto.
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277 Florence... ...*Società Africana d'Italia (Sezione Fiorentina).
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279 „ ... ...*Società Italiana di Antropologia e di Etnologia.
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281 Milan ... ...*Reale Istituto Lombardo di Scienze Lettere ed Arti.
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283 Modena ... ...*Regia Accademia di Scienze, Lettere ed Arti.
284 Naples ... ...*Società Africana d' Italia.
285 „ ... ...*Società Reale di Napoli (Accademia delle Scienze Fisiche e Matematiche).
286 „ ... ...*Statione Zoologica (Dr. Dohrn).
287 Palermo ... ...*Reale Accademia Palermitana di Scienze Lettere ed Arti.
288 „ ... ... Reale Istituto Tecnico.
289 Pisa ... ...*Società Toscana di Scienze Naturali.
290 Rome ... ...*Accademia Pontificia de Nuovi Lincei.
291 „ ... ...*Biblioteca e Archivio Tecnico (Ministero dei Lavori Pubblico).
292 „ ... ...*R. Accademia dei Lincei.
293 „ ... ...*R. Comitato Geologico d' Italia.
294 „ ... ...*R. Ufficio Centrale di Meteorologico e di Geodinamico.
295 „ ... ...*Società Geografica Italiana.
296 Siena ... ...*R. Accademia dei Fisiocritici in Siena.
297 Turin ... ...*Reale Accademia della Scienze.
298 „ ... ...*Regio Osservatorio della Regia Università.
299 Venice ... ...*Reale Istituto Veneto di Scienze, Lettere ed Arti.

Japan.

300 Tokio ... ...*Asiatic Society of Japan (formerly in Yokohama).
301 „ ... ...*Imperial University.
302 „ ... ...*Seismological Society of Japan.

Java.

303 Batavia ... ...*K. Natuurkundige Vereeniging in Nederl-Indië.

Mexico.

304 Mexico ... ...*Sociedad Cientifica "Antonio Alzate."

Netherlands.

305 Amsterdam ...*Académie Royale des Sciences.
306 „ ...*Société Royale de Zoologie.
307 Haarlem... ...*Bibliothèque de Musée Teyler.
308 „ ... ...*Colonial Museum.
309 „ ... ...*Société Hollandaise des Sciences.

Norway.

310 Bergen ... ...*Museum.
311 Christiania ...*Köngelige Norske Fredericks Universitet.
312 „ ...*Videnskabs-Selskabet i Christiania.
313 Tromso ... ...*Museum.

Roumania.

314 Bucharest ...*Institutul Meteorologic al Roumăniei.

Russia.

315 HELSINGFORS ...*Société des Sciences de Finlande.
316 KIEFF ... ...*Société des Naturalistes.
317 MOSCOW ... ...*Société Impériale des Naturalistes.
318 „ ... ...*Société Impériale des Amis des Sciences Naturelles d' Anthropologie et d' Ethnographie à Moscow (Section d' Anthropologie).
319 ST. PETERSBURG ...*Académie Impériale des Sciences.
320 „ ...*Comité Géologique—Institut des Mines.

Spain.

321 MADRID ... ... Instituto geografico y Estadistico.

Sweden.

322 STOCKHOLM ...*Kongliga Svenska Vetenskaps-Akademien.
323 „ ...*Kongliga Universitetet.
324 „ ...*Kongl. Vitterhets Historie och Antiqvitets Akademien.
325 UPSALA ... ... Kongliga Vetenskaps Societeten.

Switzerland.

326 BERNE ... ...*Société de Géographie de Berne.
327 GENEVA ... ...*Institut National Genèvois.
328 LAUSANNE ...*Société Vaudoise des Sciences Naturelles.
329 NEUCHATEL ...*Société des Sciences Naturelles de Neuchatel.
330 ZURICH ... ...*Naturforschende Gesellschaft.

United States of America.

331 ALBANY ... ...*New York State Library, Albany.
332 ANNAPOLIS (Md.) *Naval Academy.
333 BALTIMORE ...*Johns Hopkins University.
334 BELOIT (Wis.) ...*Chief Geologist.
335 BERKELEY ...*University of California.
336 BOSTON ... ...*American Academy of Arts and Sciences.
337 „ ... ...*Boston Society of Natural History.
338 „ ... ... State Library of Massachusetts.
339 BROOKVILLE (Ind.)*Brookville Society of Natural History.
340 „ ... Indiana Academy of Science.
341 BUFFALO (Ind.) ...*Buffalo Society of Natural Sciences.
342 CAMBRIDGE (Mass.)*Cambridge Entomological Club.
343 „ ...*Museum of Comparative Zoology at Harvard College.
344 CHICAGO ... ...*Academy of Sciences.
345 „ ... ... American Medical Association—The Newberry Library.
346 CINCINNATI ...*Cincinnati Society of Natural History.
347 COLDWATER ... Michigan Library Association.
348 DAVENPORT (Iowa)*Academy of Natural Sciences.
349 DENVER ... ...*Colorado Scientific Society.
340 FORT MONROE (Va.)*United States Artillery School.
351 HOBOKEN (N.J.) ...*Steven's Institute of Technology.
352 IOWA CITY (Iowa) *Director Iowa Weather Service.
353 JEFFERSON CITY...*Geological Survey of Missouri.
354 MADISON (Wis.)...*Wisconsin Academy of Sciences, Arts and Letters.
355 MINNEAPOLIS ...*Minnesota Academy of Natural Sciences.
356 NEWHAVEN (Conn) *Connecticut Academy of Arts and Sciences.
357 NEW YORK ...*American Chemical Society.
358 „ ...*American Geographical Society.
359 „ ...*American Institute of Mining Engineers.

359	New York	...*American Museum of Natural History.
360	,,	...*American Society of Civil Engineers.
361	,,	...*Editor *Journal of Comparative Medicine and Veterinary Archives.*
362	,,	...*New York Academy of Sciences.
363	,,	...*New York Microscopical Society.
364	,,	...*School of Mines, Columbia College.
365	Palo Alto (Cal.)	...*Geological Survey of Arkansas.
366	Philadelphia	...*Academy of Natural Science.
367	,,	...*American Entomological Society.
368	,,	...*American Philosophical Society.
369	,,	...*Franklin Institute.
370	,,	...*Geological Survey of Pennsylvania.
371	,,	...*Wagner Free Institute of Science.
372	,,	...*Zoological Society of Philadelphia.
373	Rochester (N.Y.)	*Geological Society of America.
374	Salem (Mass.)	...*American Association for Advancement of Science.
375	,,	...*Essex Institute.
376	St. Louis ...	...*Academy of Science.
377	,,	...*Missouri Botanical Garden.
378	San Francisco	...*California Academy of Sciences.
379	,,	...*California State Mining Bureau.
380	Scranton (Pa.)	...*The Colliery Engineer Co.
381	Washington	...*Bureau of Education (Department of the Interior).
382	,,	...*Bureau of Ethnology.
383	,,	...*Chief of Engineers (War Department).
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387	,,	...*Director of the Mint (Treasury Department).
388	,,	...*Library (Navy Department).
389	,,	...*National Academy of Sciences.
390	,,	...*Office of Indian Affairs (Department of the Interior).
391	,,	...*Philosophical Society.
392	,,	...*Secretary (Department of the Interior).
393	,,	...*Secretary (Treasury Department).
394	,,	...*Smithsonian Institution.
395	,,	...*Surgeon General (U.S. Army).
396	,,	...*U. S. Coast and Geodetic Survey (Treasury Department).
397	,,	...*U.S. Geological Survey.
398	,,	...*U. S. National Museum (Department of the Interior).
399	,,	... U.S. Patent Office.
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